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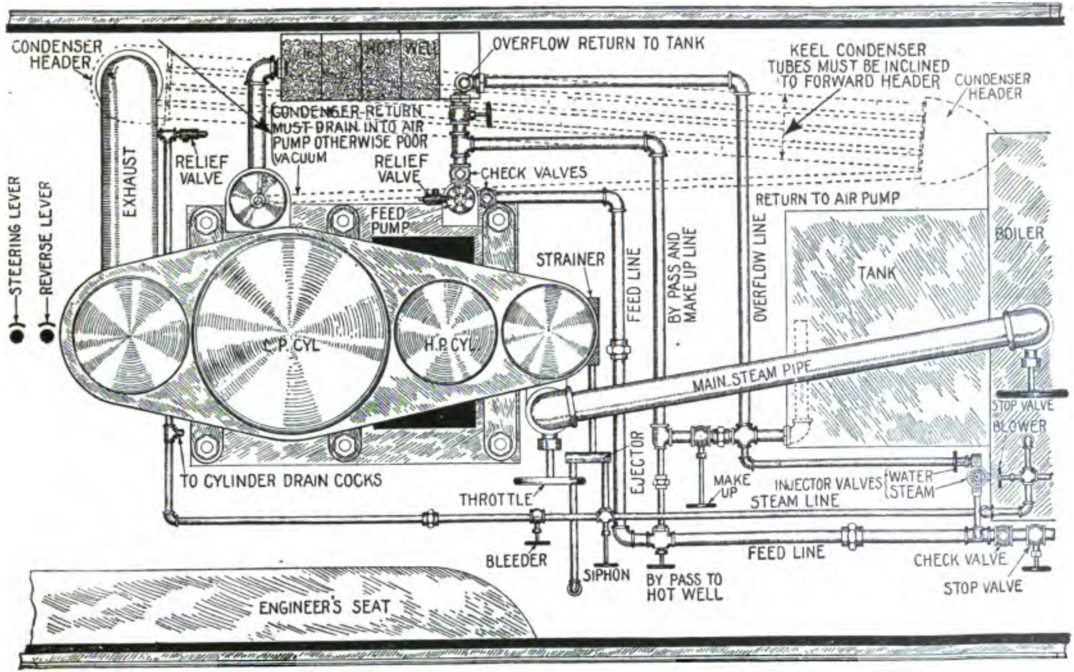

Plate 7.—General arrangement of machinery and piping of the author's steamer "Stornoway I."

With the control arranged as here shown, a boat of considerable size can be operated by one man. ***Note position:*** 1, of throttle, reverse and steering levers; 2, of by pass, make up, siphon, and bleeder valves, all within reach for engineer's seat; 3, of tank under boiler where water absorbs some heat from ash pan. ***With keel condenser,*** the tubes and return pipe *must* be inclined so *condensate will drain from condenser inlet to air pump, otherwise* ***little or no vacuum.*** Relief valves should be placed on exhaust and feed lines. ***In piping,*** use plenty of unions and avoid special fittings. Injector steam pipe should have separate boiler connection.

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ENGINEERING PROFESSION

BY

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NOTE

In planning this helpful series of Educators, it has been the aim of the author and publishers to present step by step a *logical plan of study in* ***General Engineering Practice,*** taking the middle ground in making the information readily available and showing by text, illustration, question and answer, and calculation, the theories, fundamentals and modern applications, including construction *in an* **interesting** *and* **easily understandable** *form.*

Where the question and answer form is used, the plan has been to give *short, simple* and *direct answers*, limited to one paragraph, thus simplifying the more complex matter.

In order to have adequate space for the presentation of the important matter and not to divert the attention of the reader, descriptions of machines have been excluded from the main text, being printed in smaller type under the illustrations.

Leonardo Da Vinci once said:

> "Those who give themselves to ready and rapid practice before they have learned the theory, resemble sailors who go to sea in a vessel without a rudder"

—in other words, *"a little knowledge is a dangerous thing."* Accordingly the author has endeavored to give ***as much*** *information* ***as possible*** in the space allotted to each subject.

> The author is indebted to the various manufacturers for their co-operation in furnishing cuts and information relating to their products.

These books will speak for themselves and will find their place in the great field of Engineering.

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CHAPTER 82

PIPE, FITTINGS, AND PIPE FITTING

1. PIPE

Formerly wrought iron was almost exclusively used in the manufacture of wrought pipe, but because of its expense and also on account of the improved methods in the manufacture of steel pipe, conditions have been reversed and now almost all wrought pipe is made of steel.

As mentioned in a previous chapter, the term "wrought iron pipe" is often *erroneously* used to refer to pipes made to Briggs standard sizes rather than of the material, hence, in ordering pipe, if iron pipe be wanted instead of steel, care should be taken to specify *genuine wrought iron*, or *guaranteed wrought iron* pipe.

It is customary for manufacturers to stamp each length of such pipe as *genuine wrought iron* to distinguish it from steel, and *no wrought iron pipe should be accepted* as such without the stamp.

NOTE.—The National Company state that "the wisdom of their decision to make steel pipe only is shown by the fact that between 80 and 90 per cent. of the pipe used to-day in the United States is steel pipe. In addition to the advantage of better service by using steel pipe it is possible to save from twenty to thirty per cent. on the first cost, due to the fact that pipe steel is made by machine rather than by hand process."

Wrought pipe is made either by the lap welded or butt welded process, and boiler tubes by the lap welded or seamless process. The lap, and butt processes are shown in Chapter 77, pages 2,801 and 2,802.

Briggs' Standard.—Both wrought iron and steel pipes are made to the same standard of sizes. The nominal sizes of pipe 10 inches and under, and the pitches of the threads, were for the most part established in the British tube (called "pipe" in

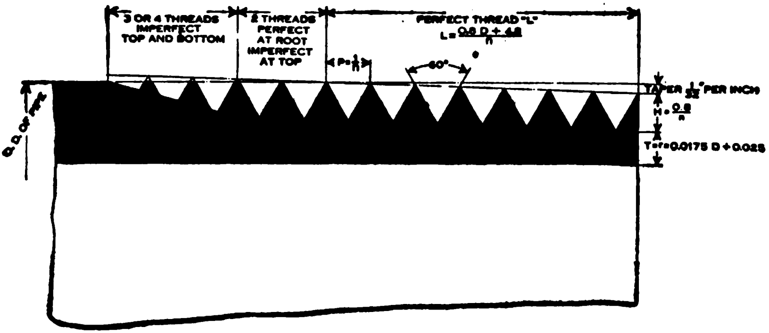

3 OR 4 THREADS IMPERFECT TOP AND BOTTOM
2 THREADS PERFECT AT ROOT IMPERFECT AT TOP
PERFECT THREAD "L"
$L = \frac{0.8 D + 4.8}{n}$
$P = \frac{1}{n}$
60°
TAPER $\frac{1}{32}$" PER INCH
$H = \frac{0.8}{n}$
T = r = 0.0175 D + 0.025
O. D. OF PIPE

FIG. 5,032.—Briggs standard pipe thread. This standard is due to Robert Briggs, C.E., who prepared a paper on "American Practice in Warming Buildings by Steam," for the Institution of Civil Engineers of Great Britain (vol. lxxi, Session 1882–83, Part 1). This paper was presented and read after his death. The following extracts from the paper (see also A. S. M. E. transactions, vol. viii), give data upon which the Briggs standard is based: "The taper employed for the conical tube ends is uniform with all makers of tubes or fittings, namely an inclination of 1 in 32 to the axis. Custom has established also a particular length of screwed end for each different diameter of tube. Tubes of the several diameters are kept in stock by manufacturers and merchants, and form the basis of a regular trade in the apparatus for warming by steam. A knowledge of all these particulars is therefore essential for designing apparatus for the purpose. The ruling dimension in wrought iron tube work is the external diameter of certain nominal sizes, which are designated roughly according to their internal diameter. These nominal sizes were mainly established in the English tube trade between 1820 and 1840, and certain pitches of screw thread were then adopted for them, the coarseness of the pitch varying roughly with the diameter, but in an arbitrary way utterly devoid of regularity. The length of the screwed portion on the tube end varies with the external diameter of the tube according to an arbitrary rule of thumb; whence results, for each size of tube, a certain minimum thickness of metal at the outer extremity of the tapering screwed tube end. It is the determination of this minimum thickness of metal, for the tapering screwed end of a wrought iron tube, which constitutes the question of mechanical interest. The figure shows a longitudinal section of the tapering tube end, with the screw thread as actually formed *full size* for a nominal 2½-inch pipe, that is a pipe about 2½ inches internal diameter and 2⅞ inches actual external diameter.

America) trade between 1820 and 1840. The sizes are designated roughly, according to their internal diameters.

Robert Briggs, about 1862, while superintendent of the Pascal Iron Works, formulated the nominal dimensions of pipe up to and including 10 inches. These dimensions have been broadly spread and are widely known as "Briggs' standard," as given in the accompanying table.

The thread has an angle of 60° and is slightly rounded off at top and bottom so that the total height (depth), $H = \frac{.8}{n}$ where n is the number of threads per inch. The pitch of the threads $\frac{1}{n}$ increases roughly with the diameter, but in an arbitrary and irregular manner. It would be advantageous to change the pitches except for the fact that they are now firmly established.

The conically threaded ends of pipe are cut at a taper of ¾ inch diameter per foot of length, that is, 1 in 32 to the axis of the pipe, as shown in fig. 5,032.

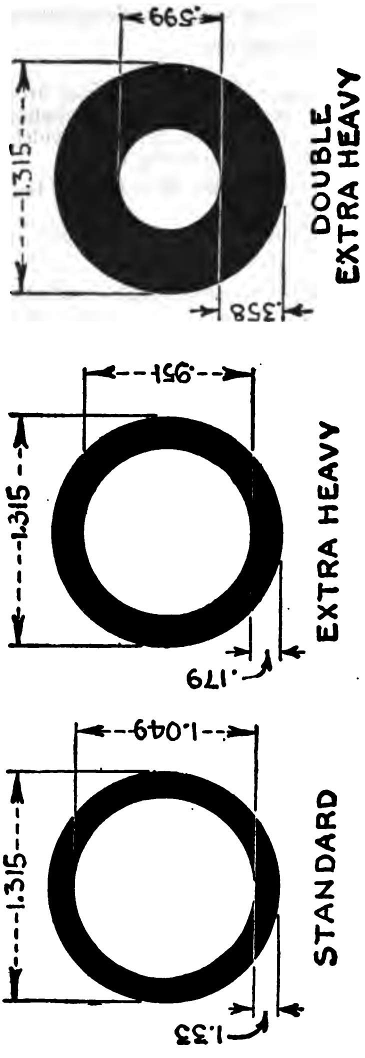
For the various sizes of pipes ranging from ⅛ to 10 inches nominal internal diameter, with their corresponding number of screw threads per inch, the actual internal diameter d, is expressed by the following table in terms of the actual external diameter D.

Diameter of Standard Wrought Pipe

Nominal internal diameter	Actual internal diameter d, in terms of actual external diameter D	Number of screw threads per inch	Depth of thread according to National Tube Co.
Inches	Inches		Inch
⅛	$d = .9631D - .1204$	27	.0296
¼ and ⅜	$d = .9622D - .1556$	18	.0444
½ and ¾	$d = .9614D - .1857$	14	.0571
1, 1¼, 1½ and 2	$d = .9607D - .2152$	11½	.0696
2½ to 10	$d = .9587D - .2875$	8	.1

Quoting from Briggs:

"The number of screw threads per inch for the several sizes of tubes is here accepted from customary usage. It is the workman's approximation



FIGS. 5,033 to 5,035.—The three weights of wrought pipe. Fig. 5,033, *standard*; fig. 5,034, *extra strong*; fig. 5,035, *double extra strong*. Sometimes the word "heavy" is used in place of strong. The figures are actual size, showing proportions of the three grades of 1-inch wrought pipe.

to the pitch practically desirable, and much reluctance must consequently be felt in calling it in question. Still it would have been better to investigate the general case upon the basis of a pitch ranging in closer accordance with the range of tube diameter. Thus the nominal ½ inch tubes might have had 16 thread per inch; ¾ inch, 14 threads; 1 and 1¼ inch, 12 threads; 1½ and 2 inches, 11 threads; 2½ to 3½ ins., 10 threads; 4 to 6 inches, 8 threads; 7 to 9 inches, 7 threads; and 10 inches, not more than 6 threads per inch. The existing numbers of threads, however (as here given), are now too well established to be disturbed; at all events they must be taken in any statement of present practice."

By trade usage, the above rules have been extended to take in sizes up to 15 inches inclusive, except that the standard thickness is .375 in. Pipes larger than 15 inches nominal size are known by their outside diameter. The dimensions have have also been extended to *extra strong* and *double extra strong* pipe, by retaining the outside diameter and allowing the inside diameter to decrease according to increase in thickness.

Weights of Pipe.—In order to adapt wrought pipe to different pressures it is regularly made up in three grades of thicknesses (weights) known as

1. Standard.
2. Extra strong (or heavy).
3. Double extra strong (or heavy).

For the three grades, the outside diameters of the listed sizes remain the same, but the thickness is increased *by decreasing the inside diameter*.

For instance, figs. 5,033 to 5,035 show sections of the above three grades of pipe of the same listed size. The following tables give properties of the three grades of wrought pipe as regularly marketed.

Ques. What is merchant pipe?

Ans. Short weight pipe.

It is necessary to guard against this short weight pipe which formerly was extensively made to meet the demand of sharp jobbers, but now reputable companies have given up the manufacture of such pipe.

Merchant pipe is usually 5 to 10 per cent thinner than full weight pipe. It should be carefully avoided in work of any importance, as the extra cost of maintenance will soon overbalance the small difference in first cost. As a precaution against merchant pipe, orders should specify full weight pipe.

Manufacture and Tests.—Welded steel pipe should be made from uniformly good quality soft, weldable steel, rolled from solid ingots. Sufficient crop should be cut from the ends to insure sound material, and the steel shall be given the most approved treatment in heating and rolling.

The steel from which the pipe is made must, according to the National Tube Co., show the following physical properties:

Tensile strength, 50,000 pounds	Elongation in 8 ins., 18 per cent
Elastic limit over 30,000 pounds	Reduction in area, 50 per cent

The following test pressures are applied to the respective sizes of butt and lap welded pipe for the three grades or weights:

Test Pressures.

National Tube Co.

STANDARD			EXTRA STRONG			DOUBLE EXTRA STRONG		
Size	Test pressure in pounds		Size	Test pressure in pounds		Size	Test pressure in pounds	
	Butt	Lap		Butt	Lap		Butt	Lap
⅛	700		⅛	700				
¼	700		¼	700				
⅜	700		⅜	700				
½	700		½	700		½	700	
¾	700		¾	700		¾	700	
1	700		1	700		1	700	
1¼	700	1,000	1¼	1,500		1¼	2,200	
1½	700	1,000	1½	1,500	2,500	1½	2,200	3,000
2	700	1,000	2	1,500	2,500	2	2,200	3,000
2½	800	1,000	2½	1,500	2,000	2½	2,200	3,000
3	800	1,000	3	1,500	2,000	3		3,000
3½		1,000	3½		2,000	3½		2,500
4		1,000	4		2,000	4		2,500
4½		1,000	4½		1,800	4½		2,000
5		1,000	5		1,800	5		2,000
6		1,000	6		1,800	6		2,000
7		1,000	7		1,500	7		2,000
8		800	8		1,500	8		2,000
8		1,000				8		
9		900	9		1,500	9		
10		600	10		1,200	10		
10		800				10		
10		900				10		
11		800	11		1,100	11		
12		600	12		1,100	12		
12		800				12		
13		700	13		1,000	13		
14		700	14		1,000	14		
15		600	15		1,000	15		

Bursting and Safe Working Pressures.—Numerous factory tests to determine the actual bursting pressure of wrought pipe have proved Barlow's formula to be correct. Barlow's formula is

$$BP=\frac{2T\times TS}{OD}$$

in which BP = bursting pressure in lbs. per sq. in.; T = thickness of the wall in ins.; OD = outside diameter of pipe in ins.; TS = tensile strength.

The value of TS as determined from actual tests by the Crane Co., is 40,000 lbs. per sq. in. for butt welded pipe and 50,000 lbs. for lap welded steel pipe. The following table is based on Barlow's formula and the working pressures given is based on a factor of safety of eight.

WROUGHT STEEL PIPE

BURSTING AND WORKING PRESSURES

	STANDARD		EXTRA STRONG		DOUBLE EXTRA STRONG		LARGE O D.			
Size Inches	Bursting Pressure Barlow's Formula	Working Pressure Factor 8	Bursting Pressure Barlow's Formula	Working Pressure Factor 8	Bursting Pressure Barlow's Formula	Working Pressure Factor 8	⅜ inch Thick Bursting Pressure Barlow's Formula	Working Pressure Factor 8	½ inch Thick Bursting Pressure Barlow's Formula	Working Pressure Factor 8
⅛	13,432	1679	18,760	3095						
¼	13,032	1629	17,624	2953						
⅜	10,784	1348	14,928	1866						
½	10,384	1298	14,000	1750	28,000	3500				
¾	8,606	1076	11,728	1716	23,464	2933				
1	8,088	1011	10,888	1611	21,776	2722				
1¼	6,744	843	9,200	1150	18,408	2301				
1½	6,104	763	8,416	1052	16,840	2105				
2	5,184	648	7,336	917	14,680	1835				
2½	5,648	706	7,680	960	15,360	1920				
3	4,936	617	6,856	857	13,714	1714				
3½	5,610	701	7,950	994	15,900	1987				
4	5,266	658	7,480	935	14,970	1871				
4½	4,940	618	7,100	887	14,200	1775				
5	4,630	579	6,740	842	13,480	1685				
6	4,220	528	6,520	815	13,040	1630				
7	3,940	493	6,550	819	11,470	1434				
8	3,730	466	5,780	722	10,140	1267				
9	3,550	444	5,190	649						
10	3,390	424	4,650	581						
12	2,940	368	3,920	490						
14							2,680	335	3,570	446
15							2,500	313	3,333	417
16							2,340	293	3,120	390
18							2,080	260	2,770	346
20							1,870	234	2,500	313
22							1,700	213	2,270	284
24							1,560	195	2,080	260

In the above table, butt welded pipe was figured on sizes 3 inch and smaller and lap welded pipe sizes 3½ inch and larger.

Ques. Are the working pressures given in the table ordinarily used on pipe lines?

Ans. No. A considerable margin must be allowed on account of the erecting and operating strains which come on the fittings.

Valves and fittings are classified under five general headings: ***1, Low pressure.***—Suitable for pressures up to 25 lbs. per sq. in.; ***2, Standard.***—Suitable for pressures up to 125 lbs.; ***3, Medium pressure.***—Suitable for pressures from 125 to 175 lbs.; ***4, Extra heavy.***—Suitable for pressures from 175 to 250 lbs.; ***5, Hydraulic.***—Suitable for water pressures up to 6,000 or more lbs.

2. FITTINGS

Since pipe cannot be obtained in unlimited lengths, and the fact that in practically all pipe installations there are numerous changes in directions, branches, etc., pipe fittings have been devised for the necessary connections. By definition the term *pipe fittings* is used to denote all those pieces that may be attached to pipes in order 1, to alter the direction of a pipe, 2, to connect a branch with a main, 3, to close an end, and 4, to connect two pipes of different sizes.*

There is an undue multiplicity of fittings on the market and the supply house that keeps all of them is indeed hard to find, hence in *pipe fitting*,* it is advisable to use only the simplest fittings, because special or unusual forms are hard to get and costly.

All these various fittings may be classed

1. With respect to material, as

    a. Cast iron.
    b. Malleable iron.
    c. Brass.
    d. Steel $\begin{cases}\text{cast}\\ \text{forged}\end{cases}$

2. With respect to design, as

    a. Plain.
    b. Beaded.

---

* NOTE.—According to the National Tube Co., couplings and valves are not considered as fittings. Couplings are excluded perhaps on account of the custom of furnishing a coupling with each length of pipe. Strictly speaking, however, the author believes that couplings should be regarded as fittings.

* NOTE.—The difference in meaning between the terms *pipe fittings* and *pipe fitting* should be noted. Thus, *pipe fittings* denotes the various devices, such as elbows, T's, etc., used in connecting pipes, and *pipe fitting*, the process of cutting, threading, and screwing the pipes and fittings together, the man who does this being called a *pipe fitter*. There are a good many persons posing as pipe fitters who have no right to the title *judging from the quality of their work*.

3. With respect to the method of connecting, as

   a. Screwed.
   b. Flanged.
   c. Ball and spigot.

4. With respect to strength, as

   a. Standard.
   b. Extra strong (or heavy).
   c. Double extra strong (or heavy).

5. With respect to the surface, as

   a. Black.
   b. Galvanized.

6. With respect to finish, as

   a. Rough.
   b. Semi-finished.
   c. Polished.

7. With respect to service, as

   a. Gas.
   b. Steam.
   c. Hydraulic (heavy pressure).
   d. Drainage.
   e. Railing.

The following definitions (from the National Tube Co.'s book of pipe standards), relating to pipes, joints, and fittings will be found helpful to the pipe fitter, and those desiring to acquire a knowledge of the subject.

Definitions

Armstrong Joint.—A two bolt, flanged or lugged connection for high pressures. The ends of the pipes are peculiarly formed to properly hold a gutta-percha ring. It was originally made for cast iron pipe. The two bolt feature has much to commend it. There are various substitutes for this joint, many of which employ rubber in place of gutta-percha; others use more bolts in order to reduce the cost.

Bell and spigot joint.—1. The usual term for the joint in cast iron pipe. Each piece is made with an enlarged diameter or bell at one end into which the plain or spigot end of another piece is inserted when laying. The joint is then made tight by cement, oakum, lead, rubber or other suitable substance, which is driven in or caulked into the bell and around the spigot. When a similar joint is made in wrought pipe by means of a cast bell (or hub), it is at times called hub and spigot joint (poor usage). Matheson joint is a name applied to a similar joint in wrought pipe which has the bell formed from the pipe. 2. Applied to fittings or valves, means that one end of the run is a "bell" and the other end is a "spigot," similar to those used on regular cast iron pipe.

Bonnet.—1. A cover used to guide and enclose the tail end of a valve spindle. 2. A cap over the end of a pipe.

Branch.—The outlet or inlet of a fitting not in line with the run, but which may make any angle.

Branch ell.—1. Used to designate an elbow having a back outlet in line with one of the outlets of the "run." It is also called a heel outlet elbow. 2. Incorrectly used to designate side outlet or back outlet elbow.

Branch pipe.—A very general term, used to signify a pipe either cast or wrought, that is equipped with one or more branches. Such pipes are used so frequently that they have acquired common names such as tees, crosses, side or back outlet elbows, manifolds, double branch elbows, etc. The term branch pipe is generally restricted to such as do not conform to usual dimensions.

Branch tee. (header).—A tee having many side branches. (See manifold.)

Bull head tee.—A tee, the branch of which is larger than the run.

Bushing.—A pipe fitting for the purpose of connecting a pipe with a fitting of larger size, being a hollow plug with internal and external threads to suit the different diameters.

Card weight pipe.—A term used to designate standard or full weight pipe, which is the Briggs' standard thickness of pipe.

Close nipple.—One of the length of which is about twice the length of a standard pipe thread and is without any shoulder.

Coupling.—A threaded sleeve used to connect two pipes. Commercial couplings are threaded to suit the exterior thread of the pipe. The term coupling is occasionally used to mean any jointing device and may be applied to either straight or reducing sizes.

Cross.—A pipe fitting with four branches arranged in pairs, each pair on one axis, and the axis at right angles. When the outlets are otherwise arranged the fittings are branch pipes or specials.

Cross over.—A fitting with a double offset, or shaped like the letter U with the ends turned out. It is only made in small sizes and used to pass the flow of one pipe past another when the pipes are in the same plane.

Cross over tee.—A fitting made along the lines similar to cross over, but having at one end two openings in a tee head the plane of which is at right angles to the plane of the cross over bend.

Cross valve.—1. A valve fitted on a transverse pipe so as to open communication at will between two parallel lines of piping. Much used in connection with oil and water arrangements, especially on ship board. 2. Usually considered as an angle valve with a back outlet in the same plane as the other two openings.

Crotch.—A fitting that has a general shape of the letter Y. Caution should be exercised not to confuse the crotch and wye ('Y).

Double branch elbow.—A fitting that, in a manner, looks like a tee, or as if two elbows had been shaved and then placed together, forming a shape something like the letter Y or a crotch.

Double sweep tee.—A tee made with easy curves between body and branch, that is, the center of the curve between run and branch lies outside the body.

Drop elbow.—A small sized ell that is frequently used where gas is put into a building. These fittings have wings cast on each side. The wings have small countersunk holes so that they may be fastened by wood screws to a ceiling or wall or framing timbers.

Drop tee.—One having the same peculiar wings as the drop elbow.

Dry joint.—One made without gasket or packing or smear of any kind, as a ground joint.

Elbow (ell).—A fitting that makes an angle between adjacent pipes. The angle is always 90 degrees, unless another angle is stated. (See Branch, Service and Union Ell.)

Extra heavy.—When applied to pipe, means pipe thicker than standard pipe; when applied to valves and fittings, indicates goods suitable for a working pressure of 250 pounds per square inch.

Header.—A large pipe into which one set of boilers is connected by suitable nozzles or tees, or similar large pipes from which a number of smaller ones lead to consuming points. Headers are often used for other purposes—for heaters or in refrigeration work. Headers are essentially branch pipes with many outlets, which are usually parallel. Largely used for tubes of water tube boilers.

Hydrostatic joint.—Used in large water mains, in which sheet lead is forced tightly into the bell of a pipe by means of the hydrostatic pressure of a liquid.

Lead joint.—1. Generally used to signify the connection between pipes which is made by pouring molten lead into the annular space between a bell and spigot, and then making the lead tight by calking. 2. Rarely used to mean the joint made by pressing the lead between adjacent pieces, as when a lead gasket is used between flanges.

Lead wool.—A material used in place of molten lead for making pipe joints. It is lead fiber, about as coarse as fine excelsior, and when made in a strand, it can be calked into the joints, making them very solid.

Line pipe.—Special brand of pipe that employs recessed and taper thread couplings, and usually greater length of thread than Briggs' standard. The pipe is also subjected to higher test.

Lip union.—1. A special form of union characterized by the lip that prevents the gasket being squeezed into the pipe so as to obstruct the flow. 2. A ring union, unless flange is specified.

Manifold.—1. A fitting with numerous branches used to convey fluids between a large pipe and several smaller pipes. (See Branch Tee.) 2. A header for a coil.

Matheson joint.—A wrought pipe joint made by enlarging one end of the pipe to form a suitable lead recess, similar to the bell of a cast iron pipe, and which receives the male or spigot end of the next length.

Practically the same style of a joint as used for cast iron pipe.

Medium pressure.—When applied to valves and fittings, means suitable for a working pressure of from 125 to 175 pounds per square inch.

Needle valve.—A valve provided with a long tapering point in place of the ordinary valve disc. The tapering point permits fine graduation of the opening. At times called a needle point valve.

Nipple.—1. A tubular pipe fitting usually threaded on both ends and under 12 inches in length. Pipe over 12 inches is regarded as cut pipe. (See Close, Short, Shoulder and Space Nipple.)

Reducer.—1. A fitting having a larger size at one end than at the other. Some have tried to establish the term "increaser"—thinking of direction of flow—but this has been due to misunderstanding of the trade custom of always giving the largest size of run of a fitting first; hence, all fittings having more than one size are reducers. They are always threaded inside unless specified flanged or for some special joint. 2. Threaded type, made with abrupt reduction. 3. Flanged pattern with taper body. 4. Flanged eccentric pattern with taper body, but flanges at 90 degrees to one side of body. 5. Misapplied at times, to a reducing coupling.

Run.—1. A length of pipe that is made of more than one piece of pipe. 2. The portion of any fitting having its ends "in line" or nearly so, in contradistinction to the branch or side opening, as of a tee. The two main openings of an ell also indicate its run, and where there is a third opening on an ell, the fitting is a "side outlet" or "back outlet" elbow, except that when all three openings are in one plane and the back outlet is in line with one of the run openings, the fitting is a "heel outlet elbow" or a "single sweep tee" or sometimes a "branch tee."

Rust joint.—Employed to secure rigid connection. The joint is made by packing the intervening space tightly with a stiff paste which oxidizes the iron, the whole rusting together and hardening into a solid mass. It generally cannot be separated except by destroying some of the pieces. One recipe is 80 pounds cast iron borings or filings, 1 pound sal-ammoniac, 2 pounds flowers of sulphur, mixed to a paste with water.

Service ell.—An elbow having an outside thread on one end. Also known as a ***street ell.***

Service pipe.—A pipe connecting mains with a dwelling.

Service tee.—A tee having inside thread on one end and on branch, but outside thread on the other end of run. Also known as ***street tee.***

Short nipple.—One whose length is a little greater than that of two threaded lengths or somewhat longer than a close nipple. It always has some unthreaded portion between the two threads.

Shoulder nipple.—A nipple any length, which has a portion of pipe between two pipe threads. As generally used, however, it is a nipple about halfway between the length of a close nipple and a short nipple.

Space nipple.—A nipple with a portion of pipe or shoulder between the two threads. It may be of any length long enough to allow a shoulder.

Standard pressure.—A term applied to valves and fittings suitable for a working steam pressure of 125 pounds per square inch.

Street elbow.—An elbow having an outside thread on one end; also called service ell.

Tee.—A fitting, either cast or wrought, that has one side outlet at right angles to the run. A single outlet branch pipe. (See Branch, Bull Head, Cross over, Double Sweep, Drop, Service and Union Tee.)

Union.—1. The usual trade term for a device used to connect pipes. It commonly consists of three pieces which are first, the thread end fitted with exterior and interior threads; second, the bottom end fitted with interior threads and a smaller exterior shoulder; and third, the ring which has made an inside flange at one end while the other end has an inside thread like that on the exterior of the thread end. A gasket is placed between the thread and bottom ends, which are drawn together by the ring. Unions are very extensively used, because they permit of connections with little disturbance of the pipe positions.

Union ell.—An ell with a male or female union at one end.

Union fitting.—An elbow or tee combined with a union.

Union joint.—The pipe coupling, usually threaded, which permits disconnection without disturbing other sections.

Union tee.—A tee with male or female union at connection on one end of run.

Wiped joint.—A lead joint in which the molten solder is poured upon the desired place, after scraping and fitting the parts together, and the joint is wiped up by hand with a moleskin or cloth paid while the metal is in a plastic condition.

Wye (y).—A fitting either cast or wrought that has one side outlet at any angle other than 90 degrees. The angle is usually 45 degrees, unless another angle is specified. The fitting indicated by the letter Y.

Cast Iron Fittings.—Standard beaded or flat band fittings of cast iron are suitable for 125 lbs. steam or 175 lbs. water pressure. These fittings will require from 1,000 to 2,500 lbs. to burst them, the large factor of safety is necessary in their use because of the strain due to expansion, contraction, weight of piping, settling and water hammer, and quality of the work of erecting, together with the possibility that they will not run uniform. For steam pressures above 125 lbs. extra heavy fittings should be used.

Malleable Iron Fittings.—Standard beaded or flat band fittings of malleable iron are intended for steam pressures up to 150 lbs. Such fittings have at various times been subjected to hydraulic pressures of from 2,000 to 4,000 lbs. without bursting them. It would accordingly seem that they would be safe for 250 lbs. steam pressure.

If proper care be exercised in fitting and using them they will undoubtedly be found satisfactory for pressures up to 500 lbs., but as all fittings are subjected to strain due to expansion, contraction, and making up the joints, they are not recommended for pressures over 150 lbs. In fact, since extra heavy fittings cost only a little more, it is in general also economy to use standard fittings for pressures above 150 lbs.

Standard plain pattern malleable fittings are used for low pressure gas and water, house plumbing and railing work.

Brass Fittings.—These are made in both standard, extra heavy, and cast iron patterns (iron pipe sizes), and are used for brass feed water pipes where bad water makes steel pipes undesirable. The standard brass fittings are usually made in sizes ¼ to 3 ins., suitable for 125 lbs. pressure; extra heavy fittings, ⅛ to 6 inches, suitable for 150 lbs. pressure; cast iron patterns in all sizes, suitable for 250 lbs.

Semi-Steel Fittings.—Extra heavy semi-steel flanged fittings as listed by Kelly Jones can be had in stock sizes from 1½ to 8 ins., tested to 2,000 lbs. hydraulic pressure and are recommended for 800 lbs. pressure. These fittings are regularly furnished with male face unless otherwise ordered.

Cast Steel Fittings.—These are made extra heavy with screwed or flanged ends. The screwed fittings are listed in sizes from 3 to 6 ins. The 3 to 4½ in. sizes inclusive are tested for 1,500 lbs. hydrostatic pressure, and the 5 and 6 in. sizes, for 1,200 lbs. pressure.

The radii of these fittings are larger than the ordinary, thereby reducing friction. They are suitable for the working pressures just given when used in hydraulic installations in which shock is absent or so slight as to be negligible.

Ordinarily these fittings, when subject to shock, should not be used for working pressures higher than 65% of the hydrostatic test pressure, and where shock is severe, 50 %, or even 40%, will be more conservative. Installations of this character should always be protected by shock absorbers placed to the best advantage.

Forged Steel Fittings.—The extra heavy hydraulic forged steel screwed fittings are suitable for superheated steam up to 2,350 lbs. pressure, a total temperature of 800° Fahr., also for cold water or oil working pressures up to 3,000 lbs. hydrostatic pressure.

They are regularly made from solid forgings in sizes ranging from ½ to 2½ ins. inclusive, and are tested to 3,000 lbs. hydraulic pressure. The double extra heavy pattern is suitable for cold water or oil working pressures up to 6,000 lbs. hydrostatic pressure. They are regularly made from solid forgings in sizes ranging from ⅜ to 2 ins. inclusive, and are tested to 6,000 lbs. hydrostatic pressure.

The Various Fittings.—There is a great multiplicity of fittings due to the many modifications of each *class* of fitting, and the several weights and different metals of which they are made. A list of names of these fittings may be divided into several groups, classified with respect to the use made of the fittings, as

1 Extension or joining.

- *a.* Nipples.
- *b.* Lock nuts.
- *c.* Couplings.
- *d.* Offsets.
- *e.* Joints.
- *f.* Unions.

2. Reducing or enlarging.

- *a.* Bushings.
- *b.* Reducers.

3. Directional.

- *a.* Offsets.
- *b.* Elbows.
- *c.* Return bends.

4. Branching.

- *a.* Side outlet elbows.
- *b.* Back outlet return bends.
- *c.* Tees.
- *d.* Y branches.
- *e.* Crosses.

5. Shut off or closing.

- *a.* Plugs.
- *b.* Caps.
- *c.* Blind flanges.

6. Union or "make up."

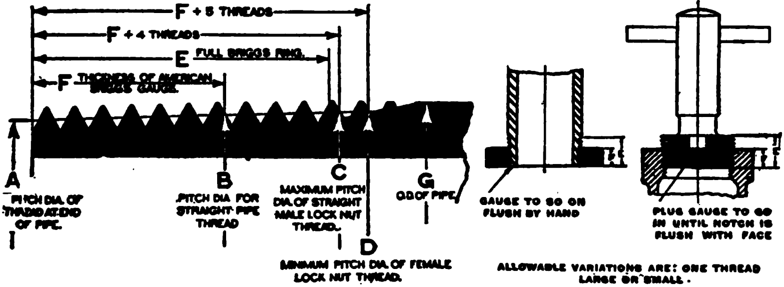
- *a.* Union elbows.
- *b.* Union tees.

1. *Extension or Joining Fittings*

Nipples.—The pipe fitter usually makes any nipples required, but usually better nipples (especially the close and short variety) can be obtained from the supply house at less cost.

AMERICAN BRIGGS STANDARD FOR TAPER AND STRAIGHT PIPE THREADS AND LOCK-NUT THREADS

ADOPTED BY THE COMMITTEE OF MANUFACTURERS ON STANDARDIZATION OF FITTINGS AND VALVES AND THE AMERICAN SOCIETY OF AMERICAN ENGINEERS
SEPTEMBER 17, 1919


F + 5 THREADS
F + 4 THREADS
E FULL BRIGGS RING.
F THICKNESS OF AMERICAN BRIGGS GAUGE.
A
PITCH DIA. OF THREAD AT END OF PIPE.
B
PITCH DIA. FOR STRAIGHT PIPE THREAD
C
MAXIMUM PITCH DIA. OF STRAIGHT MALE LOCK NUT THREAD.
D
MINIMUM PITCH DIA. OF FEMALE LOCK NUT THREAD.
G
O.D. OF PIPE
GAUGE TO GO ON FLUSH BY HAND
PLUG GAUGE TO GO IN UNTIL NOTCH IS FLUSH WITH FACE
ALLOWABLE VARIATIONS ARE: ONE THREAD LARGE OR SMALL.

Figs. 5,036 to 5,037*a*.—American Briggs standard pipe thread, and ring and plug gauges. The thread proportions are given in the formulæ and table below.

A equals $G-(0.05G+1.9)\times\frac{1}{N}+\frac{0.8}{N}$

B equals $A+(F\times.0625)$

C equals $B+\left(\frac{4}{N}\times.0625\right)$

D equals $B+\left(\frac{5}{N}\times.0625\right)$

E equals $(0.8G+4.8)\times\frac{1}{N}+\frac{2}{N}$

F equals American Briggs Standard.
N equals Number of threads per inch.
Total Taper ¾ inch per foot.
Depth of Thread $\frac{0.8}{N}$

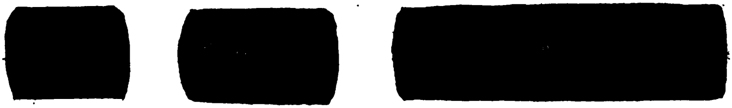
AMERICAN BRIGGS STANDARD PIPE THREADS

Size	A	B	C	D	E	F	G	Depth of Thread	Threads per Inch
⅛	.36350	.37476	.38400	38632	2638	.180	.405	.02963	27
¼	.47739	.48989	.50378	50725	.4018	.200	.540	.04444	18
⅜	.61201	.62701	.64090	.64437	.4078	.240	.675	.04444	18
½	.75843	.77843	.79628	.80075	.5337	.320	.840	.05714	14
¾	.96768	.98886	1.00671	1 01118	.5457	.339	1.050	.05714	14
1	1.21363	1 23863	1.26086	1 26590	.6828	.400	1.315	.06956	11½
1¼	1.55713	1.58338	1.60511	1 61056	.7068	.420	1.660	.06956	11½
1½	1.79609	1.82234	1.84407	1.84951	.7235	.420	1.900	.06956	11½
2	2.26902	2.29627	2.31801	2 32344	.7565	.436	2.375	.06956	11½
2½	2.71954	2.76216	2.79341	2.80122	1.1375	.682	2.875	.100	8
3	3.34063	3.38850	3.41975	3.42756	1.2000	.766	3.500	.100	8
3½	3.83750	3.88881	3.92006	3.92787	1.2500	.821	4.000	.100	8
4	4.33438	4.38713	4.41838	4.42619	1.3000	.844	4.500	.100	8
4½	4.83125	4.88593	4.91718	4 92499	1 3500	.875	5.000	.100	8
5	5.39074	5.44930	5.48055	5.48836	1.4063	.937	5.563	.100	8
6	6.44610	6.50597	6.53722	6.54503	1.5125	.958	6.625	.100	8
7	7.43985	7.50235	7.53360	7.54141	1.6125	1.000	7.625	.100	8
8	8.43360	8.50003	8.53128	8.53909	1.7125	1.063	8.625	.100	8
9	9.42735	9.49797	9.52922	9.53703	1 8125	1.130	9.625	.100	8
10	10.54532	10.62094	10 65219	10 66000	1 9250	1.21	10.750	.100	8
11	11.53907	11.61938	11.65063	11 65844	2.0250	1.285	11.750	.100	8
12	12.53282	12.61782	12.64907	12 65688	2.1250	1.360	12.750	.100	8
14 O. D.	13.7750	13.87262	13.90387	13 91168	2.250	1.562	14.00	.100	8
15 O. D.	14.76875	14.87418	14.90643	14 91324	2.350	1.687	15.00	.100	8
16 O. D.	15.76250	15.87575	15.90700	15 91481	2.450	1.812	16.00	.100	8
17 O. D.	16.75625	16.87500	16.90625	16 91406	2 550	1.900	17.00	.100	8
18 O. D.	17.7500	17.87500	17.90625	17 91406	2 650	2.000	18.00	.100	8
20 O. D.	19.73750	19.87031	19.90156	19.90937	2 850	2.125	20.00	.100	8
22 O. D.	21.72500	21.86562	21.89687	21.90468	3 050	2.250	22.00	.100	8
24 O. D.	23.71250	23.86098	23.89218	23 89999	3.250	2.375	24.00	.100	8

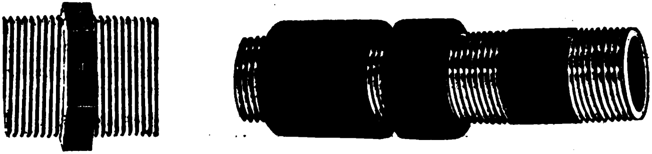
No pipe fitter deserving to be called such will attempt to cut nipples without a proper nipple holder, such as shown in fig. 5,044, although some plumbers and others are often guilty of such practice when working by the day instead of by the job.

Nipples are *short pieces of pipe* (12″ *and under*), *threaded at both ends.*

Where fittings or valves are to be very close to each other, the intervening nipple is just long enough to take the threads at each end, being called a ***close nipple***, as in fig. 5,038, but if a small amount of pipe intervene between the threads it is called a ***shoulder*** or ***short nipple***, as in fig. 5,039; where a larger amount of bare pipe intervenes it is called a ***long nipple***, as in fig. 5,040, or ***extra long nipple.*** The following table gives the standard proportion of wrought nipples:



FIGS. 5,038 to 5,040.—***Close, short*** or ***shoulder,*** and ***long*** wrought nipples. As listed by Bernard Greenwood for 1-inch pipe the length of close, short and long nipples are 1½, 2, and 2½ to 4 inches respectively. ***Extra long*** nipples are quoted as from 13 to 24 inches, but these should be regarded as cut pipe.



FIGS. 5,041 and 5,042.—Jarecki long screw nipple and right and left hexagon center nipple. The long screw nipple has one end of the coupling and follower faced to make a tight joint.

Standard Wrought Nipples

Size	1/8	1/4	3/8	1/2	3/4	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	11	12
Close	3/4	7/8	1	1⅛	1⅜	1½	1⅝	1¾	2	2½	2½	2¾	3	3	3¼	3¼	3½	3½	4	4	4	4
Short	1½	1½	1½	1½	2	2	2½	2½	2½	3	3	4	4	4	4½	4½	5	5	5	5	5	5
Long	2	2	2	2	2½	2½	3	3	3	3½	3½	4½	4½	4½	5	5	6	6	8	8		8
Long	2½	2½	2½	2½	3	3	3½	3½	3½	4	4	5	5	5	5½	5½						
Long	3½	3½	3½	3½	4	4	4½	4½	4½	5	5	6	6	6	6½	6½						

Extra long nipples are regularly made in sizes ¾ to 1⅛×4; ¾ to 2×5; ¾ to 2½×6; ¾ to 3½×7 and 8; ¾ to 12×12, with exception of 11-inch size.

Nipples having a ***right*** thread at one end and a ***left*** thread at the other are generally used in steam heating piping instead of unions. Fig. 5,041 shows a R and L (right and left thread) nipple with a hexagon nut at the center and forming part of the nipple.

Another variety is the ***long screw nipple*** shown in fig. 5,042. This has a long thread on one end on which is a coupling and locknut, the jamb surface of the coupling and lock nut being faced; the combination forms virtually a union with male and female ends.

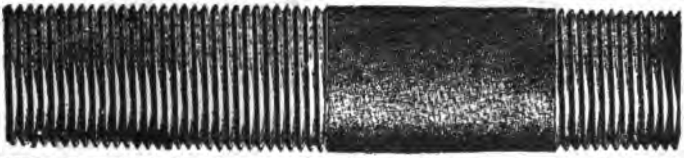


Fig. 5,043.—Tank nipple, 6 ins. long over all. Tank nipples have an American Briggs standard lock nut thread 4 ins. long on one end, and a standard pipe thread on the other end. Regularly made in sizes ¼ in. to 3 ins.

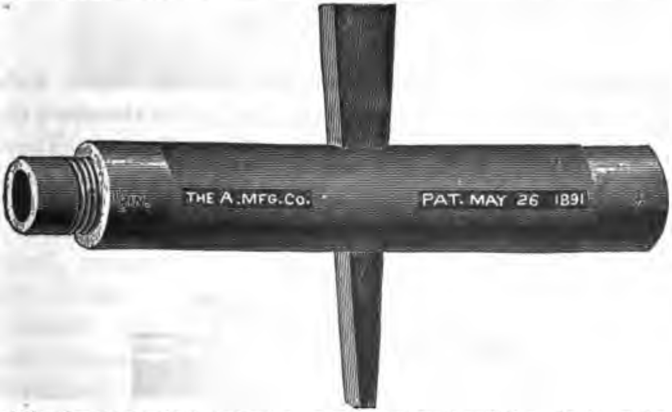
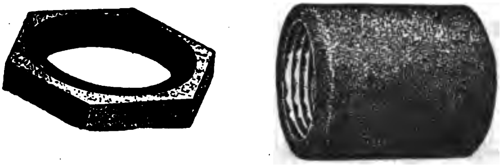


Fig. 5,044.—Armstrong nipple holder for use with hand stock and dies. As shown the holder is double ended and holds two sizes of nipples, the one illustrated being for ½ and ¾ inch nipples. ***In construction,*** there is a pin inside the holder having a fluted end which "digs into" the nipple end when pressed forward by driving down the wedge. ***In operation*** the nipple is screwed by hand into the holder as far as it will go, then the wedge is driven down sufficiently to firmly secure the nipple. The holder is so arranged that when the thread is cut, the nipple can be removed by simply starting back the wedge, which loosens the inner part of the holder and allows the nipple to be easily unscrewed by hand. The holder can be used for making either right or right and left nipples.

Fig. 5,043 shows a ***tank nipple.*** It has at one end an American Briggs, standard lock nut thread 4 ins. long, and at the other, a standard pipe thread. A heavy lock nut is used on the long thread end.

Lock Nuts.—These are made with faced end for use on long screw nipples having couplings, and with a recessed or grooved end to hold packing where this is depended upon to make a tight joint.



FIGS. 5,045 and 5,046.—Lock nut and coupling.

The use of lock nipples should be avoided wherever possible, as the joint is not so good as that obtained by a union

Couplings.—The ordinary coupling usually comes with the pipe, one coupling to each length of pipe, and is therefore classed by some as a part of the pipe rather than a fitting. These are made of wrought or cast metal and of brass; they are regularly

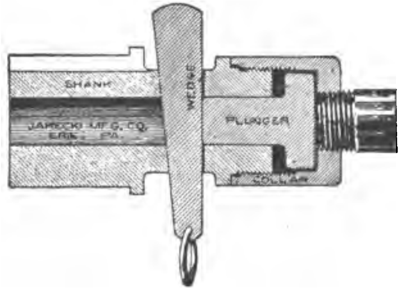
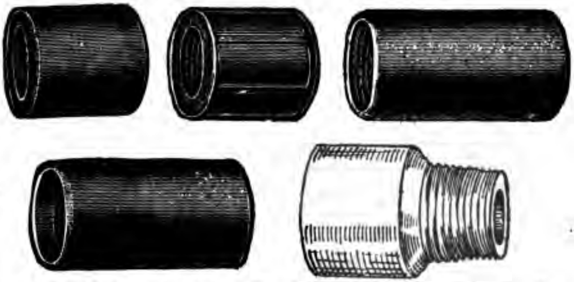


FIG. 5,047.—Jarecki nipple holder for threading close and short nipples.

threaded right hand, but can be obtained with R and L thread. R and L couplings have projecting bars or rings to distinguish them from couplings with right thread only. Figs. 5,048 to 5,051 show four kinds of couplings. Another form called an *extension piece* is shown in fig. 5,052; it differs from the standard coupling in that it has a male thread at one end. There are numerous other types, some being known as *reducers* and others as *joints*.

Joints.—There are on the market a number of special couplings or *joints* such as ammonia, Armstrong, bull, bell and spigot, block, bumped, butted and strapped, Converse, lock, corrugated, crossed artesian, cup, cup and ball, dresser, drive pipe, dry, Eckert, expanded, expansion, Field, flanged, flexible, flush, ground, hydrostatic, inserted, Kimberly, knock off, lead, lead and rubber, line pipe, Matheson, National, Normandy, peeved flanged, Perkins, Petit's Pope, pressure, Riedler, rust, shrink, Siemens, slip, socket, spigot, swing, swivel, thimble, Van Stone, Walker, welded flange and wiped joint.

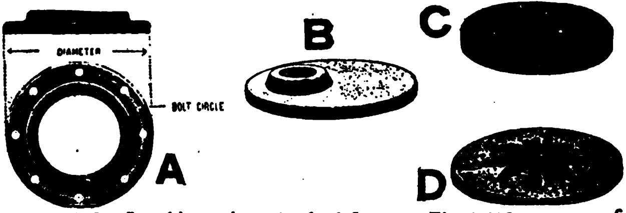


FIGS. 5,048 to 5,052.—Various couplings. Fig. 5,048, standard wrought coupling; fig. 5,049, malleable R and L (right and left) coupling; fig. 5,050, hydraulic coupling; fig. 5,051, sleeve coupling. Notice length of hydraulic and sleeve couplings as compared to the standard R and L. In fig. 5,051 the projecting sleeve is seen which covers the exposed threads beyond the joint; fig. 5,052, extension piece or coupling with male and female threads.

A number of these are described in the definitions, and particulars of the others may be obtained from the National Tube Co. book of standards.

Dimensions of Standard Flanges

American Standard for 125 lbs. Working Pressure
In effect January 1st, 1915



FIGS. 5,053 to 5,056.—Jarecki cast iron standard flanges. Fig. 5,053, common; fig. 5,054, eccentric; fig. 5,055, solid 16 in. *o.d.* and smaller; fig. 5,056, solid 19 in. *o.d.* and smaller.

Pipe Size Inches.	Outside Diameter of Flanges Inches.	Thickness of Flanges Inches.	Thickness Through Boss Inches.	Bolt Circle Inches.	Number of Bolts.	Size of Bolts Inches.
1	4	7/16	11/16	3	4	7/16x1½
1¼	4½	½	¾	3⅜	4	7/16x1½
1½	5	9/16	⅞	3⅞	4	½x1¾
2	6	⅝	1	4¾	4	⅝x2
2½	7	11/16	1 1/16	5½	4	⅝x2¼
3	7½	¾	1⅛	6	4	⅝x2½
3½	8½	13/16	1 3/16	7	4	⅝x2½
4	9	15/16	1 5/16	7½	8	⅝x2¾
4½	9¼	15/16	1⅜	7¾	8	¾x3
5	10	15/16	1 7/16	8½	8	¾x3
6	11	1	1 9/16	9½	8	¾x3
7	12½	1 1/16	1½	10¾	8	¾x3
8	13½	1⅛	1⅝	11¾	8	¾x3¼
9	15	1⅛	1¾	13¼	12	¾x3¼
10	16	1 3/16	1⅞	14¼	12	¾x3½
12	19	1¼	2 3/16	17	12	⅞x3½
14	21	1⅜	2 5/16	18¾	12	1 x4¼
15	22¼	1⅜	2 3/16	20	16	1 x4¼
16	23½	1 7/16	2 3/16	21¼	16	1 x4½
18	25	1 9/16	2 3/16	22¾	16	1⅛x4¾
20	27½	1 11/16	2⅝	25	20	1⅛x5
22	29½	1 13/16	2¾	27¼	20	1¼x5¼
24	32	1⅞	2⅞	29½	20	1¼x5½

Bolt holes are drilled ⅛-inch larger than nominal diameter of bolts

Dimensions of Extra Heavy Flanges

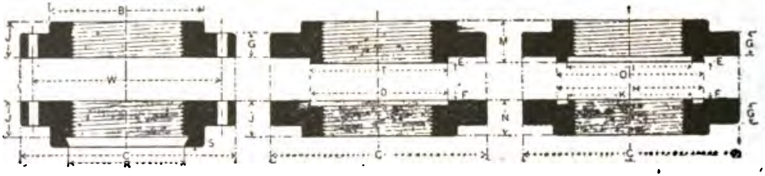
American Standard for 250 lbs. Working Pressure
In effect January 1st, 1915

Figs. 5,057 to 5,059.—Jarecki cast iron extra heavy flanges. **A**, solid 16 in. and smaller, plain face; **B**, solid 18 in. and larger; **C**, eccentric plain face.

PIPE SIZE. Inches.	Diameter of Flanges.	Thickness of Flanges.	Bolt Circle.	Number of Bolts.	Size of Bolts.	Length of Bolts.
1	4⅞	11/16	3¼	4	½	2
1¼	5	¾	3¾	4	½	2¼
1½	6	13/16	4½	4	⅝	2½
2	6½	⅞	5	4	⅝	2½
2½	7½	1	5⅞	4	¾	3
3	8¼	1⅛	6⅝	8	¾	3
3½	9	1 3/16	7¼	8	¾	3¼
4	10	1¼	7⅞	8	¾	3½
4½	10½	1 5/16	8½	8	¾	3½
5	11	1⅜	9¼	8	¾	3¾
6	12½	1 7/16	10⅝	12	¾	3¾
7	14	1½	11⅞	12	⅞	4
8	15	1⅝	13	12	⅞	4¼
9	16¼	1¾	14	12	1	4½
10	17½	1⅞	15¼	16	1	4¾
12	20½	2	17¾	16	1⅛	5
14	23	2⅛	20¼	20	1⅛	5¼
15	24½	2 3/16	21½	20	1¼	5½
16	25½	2¼	22½	20	1¼	5¾
18	28	2⅜	24¾	24	1¼	6
20	30½	2½	27	24	1⅜	6½
22	33	2⅝	29¼	24	1½	6¾
24	36	2¾	32	24	1⅝	7

Bolt holes are drilled ⅛-inch larger than nominal diameter of bolts.

EXTRA HEAVY CAST IRON FLANGES



FIGS. 5,060 to 5,062.—Various extra heavy cast iron flanges. Fig. 5,060, plain straight faces; fig. 5,061, male and female faces; fig. 5,062, tongue and groove faces.

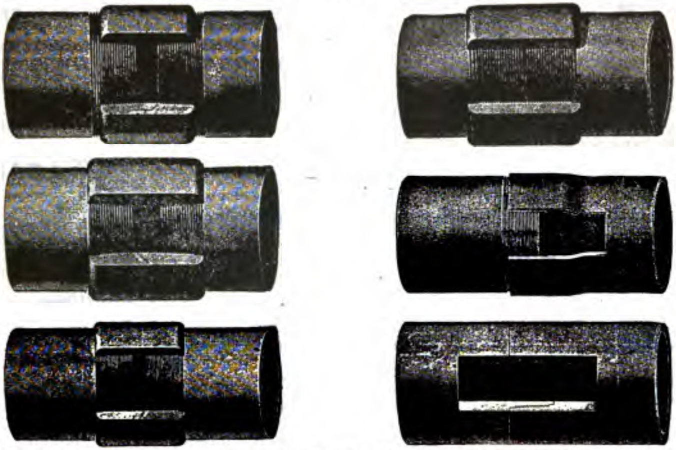
TABLE OF DIMENSIONS

Size,	Inches	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
B—Hub Diameter	Inches	2 1/16	2½	2⅞	3 3/16	4	4⅝	5¼	5¾	6 5/16	6¾	7 13/16	9	10⅛	11 1/16	12⅜	14⅜	15⅞	16 13/16	18	20⅛	22 5/16	24½	26¾
C—Diameter of Flange	Inches	4½	5	6	6½	7½	8¼	9	10	10½	11	12½	14	15	16¼	17½	20½	23	24½	25½	28	30½	33	36
G—Thickness of Flange	Inches	11/16	¾	13/16	⅞	1	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16	1½	1⅝	1¾	1⅞	2	2⅛	2 3/16	2¼	2⅜	2½	2⅝	2¾
J—Thickness through Boss	Inches	1	1⅛	1¼	1⅜	1 7/16	1 9/16	1⅝	1¾	1 13/16	1⅞	2	2 1/16	2 3/16	2¼	2⅜	2 9/16	2 11/16	2 13/16	2⅞	3 1/16	3¼	3 7/16	3⅝
W—Diameter of Bolt Circle	Inches	3¼	3¾	4½	5	5⅞	6⅝	7¼	7⅞	8½	9¼	10⅝	11⅞	13	14	15¼	17¾	20¼	21½	22½	24¾	27	29¼	32
Number of Bolts		4	4	4	4	4	8	8	8	8	8	12	12	12	12	16	16	20	20	20	24	24	24	24
Size of Bolts	Inches	½	½	⅝	⅝	¾	¾	¾	¾	¾	¾	¾	⅞	⅞	1	1	1⅛	1⅛	1¼	1¼	1¼	1⅜	1½	1⅝
Length of Bolts	Inches	2	2¼	2½	2½	3	3¼	3¼	3½	3½	3¾	3¾	4	4¼	4¾	5	5½	5¾	6	6	6¼	6¾	7	7½
Diameter of Bolt Holes	Inches	⅝	⅝	¾	¾	⅞	⅞	⅞	⅞	⅞	⅞	⅞	1	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1⅜	1½	1⅝	1¾
I—Inside Diameter of Tongue	Inches	1¾	2⅛	2¾	3⅛	3⅝	4¼	4¾	5¼	5¾	6¼	7½	8⅝	9⅝	10⅝	11⅝	13⅝	15⅞	17⅛	18⅜	20⅜	22 5/16	24½	26½
O—Outside Diameter of Tongue	Inches	2½	3	3⅝	4⅛	4⅝	5¼	5¾	6¼	6¾	7¼	8½	9⅝	10⅞	11⅞	13⅛	15⅛	17⅜	18⅝	20⅛	22⅜	24 5/16	26½	28½
E—Height of Tongue (Male)	Inches	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼
K—Inside Diameter of Groove	Inches	1 11/16	2 1/16	2 11/16	3 1/16	3 9/16	4 3/16	4 11/16	5 3/16	5 11/16	6 3/16	7 7/16	8 9/16	9 9/16	10 9/16	11 9/16	13 9/16	15 13/16	17 1/16	18 5/16	20 5/16	22¼	24 7/16	26 7/16
H—Outside Diameter of Groove	Inches	2 9/16	3 1/16	3 11/16	4 3/16	4 11/16	5 5/16	5 13/16	6 5/16	6 13/16	7 5/16	8 9/16	9 11/16	10 15/16	11 15/16	13 3/16	15 3/16	17 7/16	18 11/16	20 3/16	22 7/16	24⅜	26 9/16	28 9/16
F—Depth of Groove (Female)	Inches	⅛	⅛	⅛	⅛	⅛	⅛	⅛	⅛	⅛	⅛	⅛	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16
T—Diameter of Tongue (Male)	Inches	2 5/16	2¾	3⅛	3⅝	4⅛	5	5½	6	6½	7¼	8⅜	9⅜	10⅝	11⅝	12¾	15¼	16½	17½	18½	21	23	25½	27½
D—Diameter of Recess (Female)	Inches	2⅜	2 13/16	3 3/16	3 11/16	4 3/16	5 1/16	5 9/16	6 1/16	6 9/16	7 5/16	8 7/16	9 7/16	10 11/16	11 11/16	12 13/16	15 5/16	16 9/16	17 9/16	18 9/16	21 1/16	23 1/16	25 9/16	27 9/16
R—Diameter of Calking Recess	Inches				2⅞	3⅜	4	4½	5	5½	6 1/16	7⅛	8⅛	9⅛	10⅛	11¼	13¼	14½	15½	16½	18½	20½	22½	24½
S—Depth of Calking Recess	Inches				½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½
Width of Calking Recess—Inches, At top					¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼
Width of Calking Recess—Inches, At bottom					3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16
M—Height of Flange without Recess (Male)	Inches				1 9/16	1⅝	1¾	1 13/16	1 13/16	2	2 1/16	2 3/16	2 3/16	2 5/16	2½	2⅝	2 13/16	2 13/16	3 1/16	3⅛	3 3/16	3½		
N—Height of Flange, without Recess (Female)	Inches				1½	1 9/16	1 11/16	1¾	1⅞	1 15/16	2	2⅛	2¼	2⅜	2 7/16	2 9/16	2¾	2⅞	3	3 1/16	3¼	3 5/16		

The most important of these are the screw or threaded joint (already described), and the flanged joint. Figs. 5,063 to 5,068 show various screwed joints. The accompanying tables give dimensions necessary for drilling templates of flanged valves, flanged fittings and flanges for standard and extra heavy pressures.

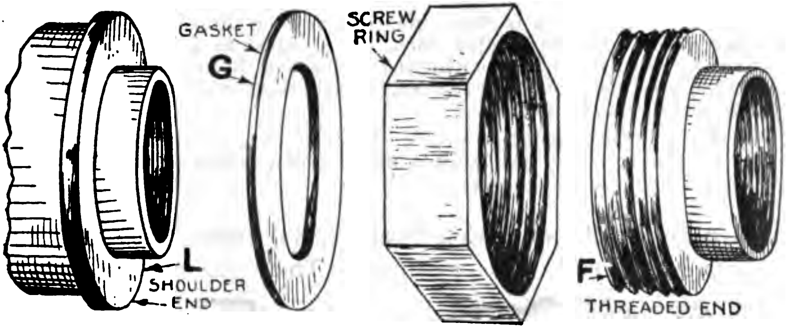
Figs. 5,060 to 5,062 show three kinds of flanges: plain, recessed and tongue and groove. The latter is intended for a caulking ring of soft metal to be placed in the groove.

Unions.—The definition (page 2,833) plainly describes the construction of an ordinary union. There are various kinds of unions. The plain union, as shown in figs. 5,069 to 5,072, requires a gasket and incidentally the two pipes to be joined by the union must be in pretty good alignment to secure a tight joint, because of the flat surfaces which must press against the gasket. This limitation is shown in figs. 5,073 and 5,074.

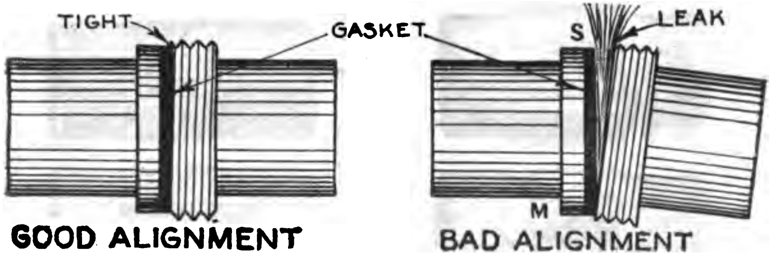


FIGS. 5,063 to 5,068.—Various screwed joints. Fig. 5,063, standard pipe joint; fig. 5,064, line pipe joint; fig. 5,065, casing joint; fig. 5,066, drive pipe joint; fig. 5,067, inserted joint casing; fig. 5,068, flush joint tubing.

To avoid this difficulty and also the inconvenience of the gasket, various unions have been devised, having spherical seats and ground joints. The latter, in some, consists of a composition ring bearing against iron, and in



FIGS. 5,069 to 5,072.—Ordinary malleable union disassembled to show parts. ***It consists of*** three parts and a gasket, as shown. ***In assembling*** the gasket G, is placed over the projection on the shoulder and so that it is in contact with surface L. The ring is slipped over the shoulder end and the threaded end placed in position so that the flat end surface F, presses against the gasket and then the ring is screwed firmly into the threaded end. Since the shoulder on the shoulder end cannot back off the ring, the two ends are pressed firmly together against the gasket by the ring, thus securing a light joint.



FIGS. 5,073 and 5,074.—Limitation of the ordinary gasket union. ***The alignment must be good to secure a tight joint.*** In the figure the ring is omitted for clearness. If both ends be in line and firmly pressed together against the gasket by the ring, the gasket will bear evenly over the entire contact surfaces and the joint will be tight. If the two ends be out of alignment when the ring is screwed tight it will bring great pressure on the gasket at M, whereas the surfaces will not come together at the opposite point S, thus causing a leak.

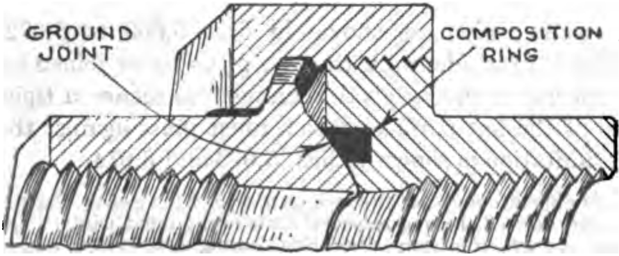


FIG. 5,075.—Jefferson brass to iron ground joint; sectional view, showing construction of joint. The composition ring is forced into the grove under great hydraulic pressure and becomes virtually a part of the grooved edd.

others both contact surfaces are composition. Fig. 5,076 shows the construction of the first mentioned joint and fig. 5,077 a flanged union with spherical ground joint. The joint of the union in fig. 5,076 has spherical contact and the illustration shows the tight joint secured by the form of a contact, even though the pipes be out of line. Unions are also made entirely of brass with ground joints.

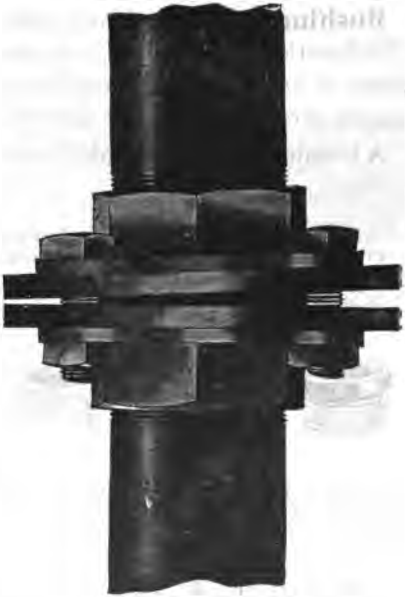


FIG. 5,076.—Jefferson flange, brass to iron, ground joint female union, illustrating the *range* of the spherical ground seat in obtaining a tight joint with pipes out of alignment.

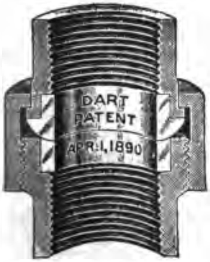


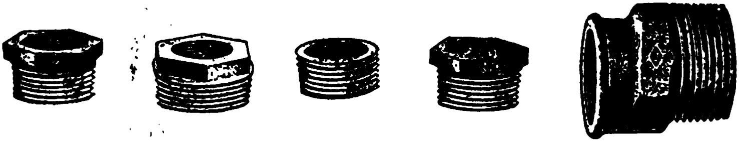
FIG. 5,077.—Dart double composition seat spherical ground joint, female union, illustrating composition to composition contact.

2. Reducing or Enlarging Fittings

Bushings.—These fittings are often confused with reducers. The function of a bushing is *to connect the male end of a pipe to a fitting of larger size.* It consists of a hollow plug with male and female threads to suit the different diameters.

A bushing may be regarded as either a reducing or an enlarging fitting.

As generally manufactured, bushings 2½ inches and smaller reducing one size are malleable iron; reducing two or more sizes are cast iron, all above 2½ inches are cast iron except brass bushings, which may be obtained in sizes from ¼ to 4 inches.



Figs. 5,078 to 5,082.—Various Jarecki bushings. Fig. 5,078, plain heavy nut bushing reducing one size; fig. 5,079, plain hexagon nut bushing, reducing more than one size; fig. 5,080, faced bushing, fig. 5,081, eccentric bushing, reducing two or more sizes; fig. 5,082, offset bushing.

Bushings are listed by the *pipe size of the* ***male thread***, thus a "¼ bushing" joins a ¼ fitting to a ⅛ pipe. It is better, however, in ordering, to avoid mistakes to specify both threads, calling for instance, the bushing just mentioned a ¼×⅛ bushing.

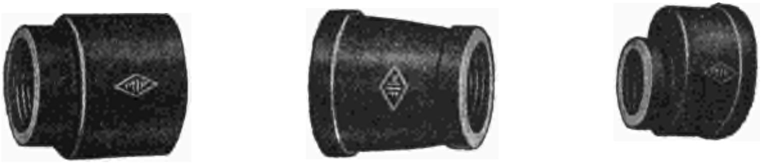
The regular pattern bushing has a hexagon nut at the female end for screwing the bushing into the fitting.

For very close work, the *faced* bushing is used, having in place of the hexagon nut a faced end. This may be used with a long screw pipe and faced lock nut to form a tight joint or to receive a male end fitting for close work. Figs. 5,079 and 5,080 show the plain and faced types of bushing.

A form valuable where drainage of the pipe line is desired, is the eccentric bushing shown in fig. 5,081. Another form is the offset bushing shown in fig. 5,082.

Reducers.—The term reducer originated from the trade custom of always giving the larger size of a run of a fitting first, and as applied, it means a reducing or enlarging coupling having female threads at both ends, as distinguished from a bushing which has both male and female threads.

Figs. 5,083 to 5,085 show various types of reducer. These are to be had in a great variety of stock sizes.



FIGS. 5,083 to 5,085.—Various M. I. F. reducers. Fig. 5,083, plain reducer for gas or low pressure fig. 5,084, flat band or reinforced reducer for steam; fig. 5,085, eccentric reducer.

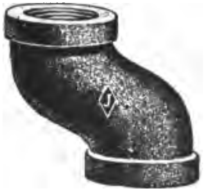


FIG. 5,086.—Jarecki standard cast iron offset. Regular sizes ¾ to 6 inches, to offset, 4, 6, or 8 inches.

3. Directional Fittings

Offsets.—In piping sometimes part of the pipe line must be in a position parallel to, but not in alignment with the balance of the pipe. An experienced pipe fitter can offset the line by bending the pipe, but ordinarily where the offset or distance between the two pipe axes is of standard dimension, a fitting

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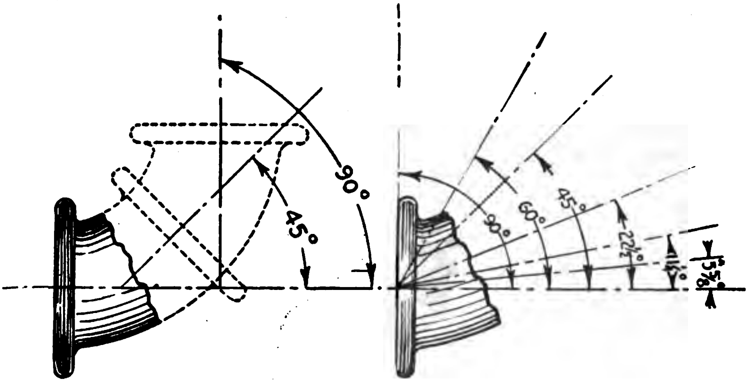
NOTE—In addition to bushings and reducers, there are other reducers or enlarging fittings as reducing elbows, tees (so called) etc. which are later described.

called an offset, as shown in fig. 5,086, can be more conveniently used.

Elbows.—Where it is necessary to change the direction of a pipe line in any of several standard and special angles, elbows are used. For gas, water and steam the standard angles are 45° and 90° and the special angles are 22½° and 60°.



Figs. 5,087 and 5,088.—Standard elbow angles. Fig. 5,087, standard for gas, water and steam; fig. 5,088, standard for drainage fittings. ***For steam,*** special angles, such as 22½° and 60°, although they can be regularly obtained from most supply houses, are best avoided where possible.

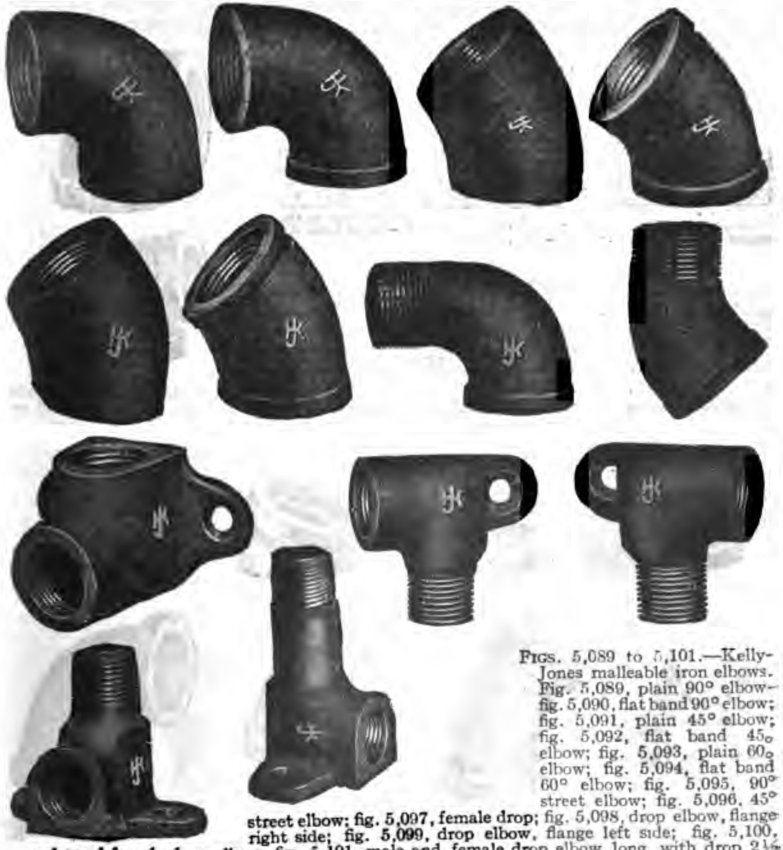
Cast iron drainage fitting elbows are regularly made with angles of 5⅝°, 11¼°, 22½°, 45°, 60°, 90°.

Elbow angles measure the degree that the direction is changed, as shown in figs. 5,087 and 5,088; these figures should be carefully noted to avoid confusion. The angle is ***not the angle between the two arms but the angle between the axis of one arm and the projected axis of the other arm,*** as in figs. 5,087 and 5,088.

There is a large variety of elbows. Figs. 5,089 to 5,101 show some standard patterns; figs. 5,102 and 5,103, R and L, and reducing cast iron elbows; figs. 5,104 to 5.111, various cast iron drainage elbows.

Return Bends.—These are largely used for making up pipe coils for steam heating and for water tube boilers. They are U-shaped fittings, with a female thread at both ends, and are regularly made in three patterns known as

1. Close. 2. Medium. 3. Open.



Figs. 5,089 to 5,101.—Kelly-Jones malleable iron elbows. Fig. 5,089, plain 90° elbow—fig. 5,090, flat band 90° elbow; fig. 5,091, plain 45° elbow; fig. 5,092, flat band 45° elbow; fig. 5,093, plain 60° elbow; fig. 5,094, flat band 60° elbow; fig. 5,095, 90° street elbow; fig. 5,096, 45° street elbow; fig. 5,097, female drop; fig. 5,098, drop elbow, flange right side; fig. 5,099, drop elbow, flange left side; fig. 5,100, male and female drop elbow; fig. 5,101, male and female drop elbow long, with drop 2½ ins. long.

Some manufacturers also make an extra close, and extra wide pattern. These patterns represent various widths between the two arms.

There seems to be no standard as to the spacing of the arms for the different patterns, hence for close work *the fitter should ascertain the center to center dimensions of the make to be used from the manufacturer's catalogue.* The table on the following page shows dimensions of the various patterns as made by Jarecki Mfg. Co. Compare with Crane dimensions below.

Malleable Return Bends

(Dimensions as made by Crane & Co.)

RETURN BENDS, CLOSE OR MEDIUM PATTERNS

Size.......................Inches	½	¾	1	1¼	1½	2
Center to Center, Close......Inches	1	1¼	1½	1¾	2 1/16	2½
Center to Center, Medium..Inches	1¼	1½	1½	2¼	2½	3

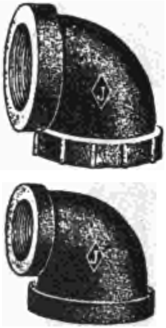
Close Pattern Return Bends will not make up parallel coils, as the distance, center to center, of two adjacent bends is greater than the center to center of openings of a single bend.

RETURN BENDS, OPEN PATTERN

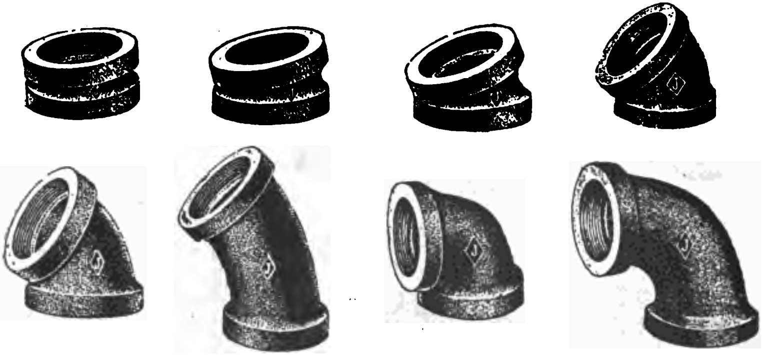
Size.............Inches	½	¾	1	1¼	1½	2	2½	3
Center to Center..........Inches			5	7½	8	6	12	
Center to Center. Inches	1½	2	2½	3	3½	4	4½	5

RETURN BENDS, SPECIAL WIDE PATTERN, RIGHT HAND

Size.......................Inches	⅜	½	¾	1	1¼	1½
Center to Center..........Inches	1½	4	6	6	6	6



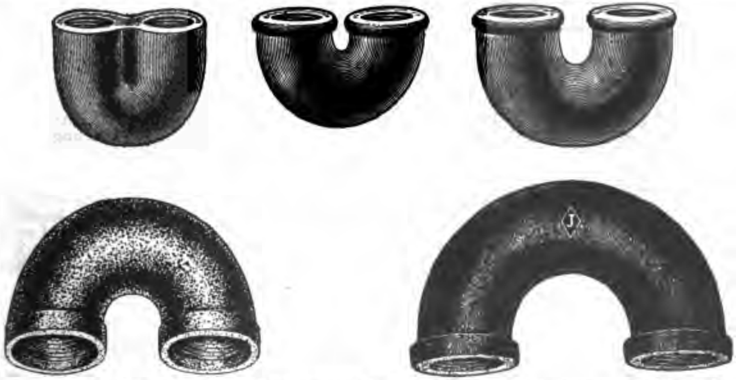
FIGS. 5,102 and 5,103.—Right and left (R and L), and reducing cast iron elbows.



FIGS. 5,104 to 5,111.—Various cast iron drainage elbows. Fig. 5,104, 1/64 bend, or 5⅝° elbow, fig. 5,105, 1/32 bend, or 11¼° short elbow; fig. 5,106, 1/16 bend, or 22½° short elbow; fig. 5,107, 1/12 bend, or 30° short elbow; fig. 5,108, ⅛ bend or 45° short elbow; fig. 5,109, ⅛ elbow, or 45° long elbow; fig. 5,110, ¼ bend, or 90° short elbow; fig. 5,111, ¼ bend, or 90° long elbow

Malleable Return Bends
(Dimensions as manufactured by Jarecki Mfg. Co.)

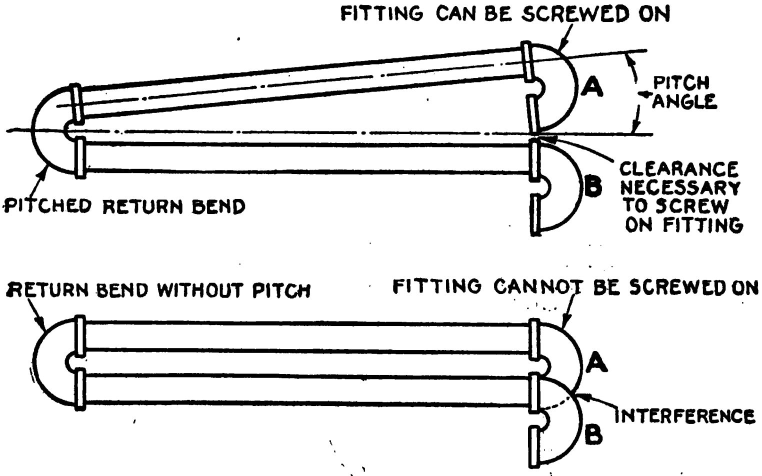
Size	Extra close		Close		Medium		Open		Wide
	Center to center	Weight per 100 plain	Center to center	Weight per 100 banded	Center to center	Weight per 100 banded	Center to center	Weight per 100	Center to center
¼	......	......	¾	15.5	......	......	1⅛	21	......
⅜	......	......	⅞	22	......	......	1¼	22	......
½	......	......	1⅛	35	1¼	34	1½	44	......
¾	1¼	77	1⅜	71	1 9/16	60	2	83	6
1	1 9/16	92	1¾	100	1⅞	92	2½	140	3 4,4½, 5,6,7,8
1¼	......	......	2⅛	168	2¼	160	3	200	4,5,6,9
1½	......	......	2½	244	2 9/16	255	3½	310	5,6,8
2	......	......	2¾	388	3 1/16	337	4⅜	550	2,6,7,8
2½	......	......	3⅞	631	......	......	4¾	710	......
3	......	......	4½	880	......	......	6¼	1,050	......
3½	......	......	5	1,400	......	......	6½	1,550	......
4	......	......	......	......	......	......	7	1,850	......
5	......	......	6	......	......	......	......	......	......



FIGS. 5,112 to 5,116.—Jarecki malleable return bends. Fig. 5,112, close pattern without bead; fig. 5,113 close pattern with bead; fig. 5,114, medium pattern; fig. 5,115, open pattern; fig. 5,116, wide pattern.

Return bends smaller than the ½ inch size are difficult to get as very few manufacturers make them, hence it should be noted that the Jarecki return bends are made in the ¼ and ⅜ sizes according to the above list.

For making up so called "coils" of short lengths of pipe, return bends may be obtained tapped with "pitch," that is, so the pipes when screwed into the fitting will not be parallel but spread like the sides of the letter V. Such bends are usually listed with minimum pipe lengths for which the pitch is suitable. For instance, Crane Co. list such bends as follows:


FITTING CAN BE SCREWED ON
A
PITCH ANGLE
CLEARANCE NECESSARY TO SCREW ON FITTING
B
PITCHED RETURN BEND
RETURN BEND WITHOUT PITCH
FITTING CANNOT BE SCREWED ON
A
INTERFERENCE
B

FIGS. 5,117 and 5,118.—Coil being made up with short pipe lengths and with return bends having "pitch" and no pitch. *If the threads* be tapped in the fitting at a slight angle so that the pipes will be inclined to each other as in fig. 5,117, there will be room enough to screw on bend A, without encountering fitting B. *If the bends* have no pitch, as in fig. 5,118, then in screwing on bend A, the other bend B, will be in the way, making it difficult to screw on A. Of course this interference may be overcome in special cases by prying the pipe ends apart with a wedge. The author made up a number of ½-inch coils with 2-foot pipe lengths by this method. The minimum length of pipe that can be made up in this way will, of course, depend on the size, and is best determined by experiment. With ½-inch pipe, the 2-foot length is about as short as should be used, though it is probably possible to reduce the length to 1½ feet.

Pitched Return Bends
(Close pattern)

Size in inches.............	1	1	1	1	1	1¼	1¼	1¼
Length of pipe in coil feet..	3	4	5	6	8	4	5	6

4. Branching Fittings

Side Outlet Elbows.—The two openings of an elbow indicate its *run*, and when there is a third opening, the axis of which is at 90° to the plane of the run, the fitting is a side outlet elbow, as shown in figs. 5,119 and 5,120. These fittings are regularly made in sizes ranging from ¼ to 2 ins. inclusive, with all

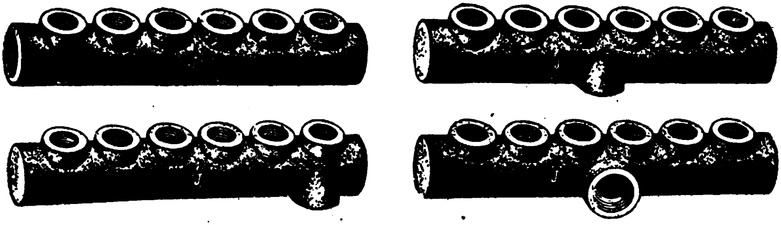
FIGS. 5,119 and 5,120.—Jarecki plain or gas pattern malleable and cast iron elbow with side outlet. ***Sizes and weights per 100:*** ¼×¼×¼, — lbs; ⅜×⅜×¼, 14 lbs; ⅜×⅜×⅜, 17 pounds; ½×½×⅜, 24 pounds; ½×½×½, 30 pounds; ¾×¾×⅜, 29 pounds; ¾×¾×½, 30 pounds; ¾×¾×¾, 33 pounds; 1×1×⅜, 52 pounds; 1×1×½, 51 pounds; 1×1×¾, 48 pounds; 1×1×1, 55 pounds; 1¼×1¼×1, 110 pounds; 1¼×1¼×1¼ 120 pounds; 1½×1½×1¼, 150 pounds; 2×2×2, 200 pounds.

FIGS. 5,121 and 5,122.—Jarecki cast iron return bends with back and side outlet. Fig. 5,121, back outlet fig. 5,122, side outlet.

outlets of equal size, and with side outlet one and two sizes smaller than rim outlets.

In general it is not well to specify too often fittings of this kind which are not so much in demand as the more usual forms because they are sometimes difficult to get.

Back and Side Outlet Return Bends.—These are simply return bends provided with an additional outlet at the back or side as shown respectively in figs. 5,125 and 5,126. They are regularly made in sizes ranging from ¾ to 3 ins. inclusive, in the close or open patterns, tapped right hand or right and left, as follows:



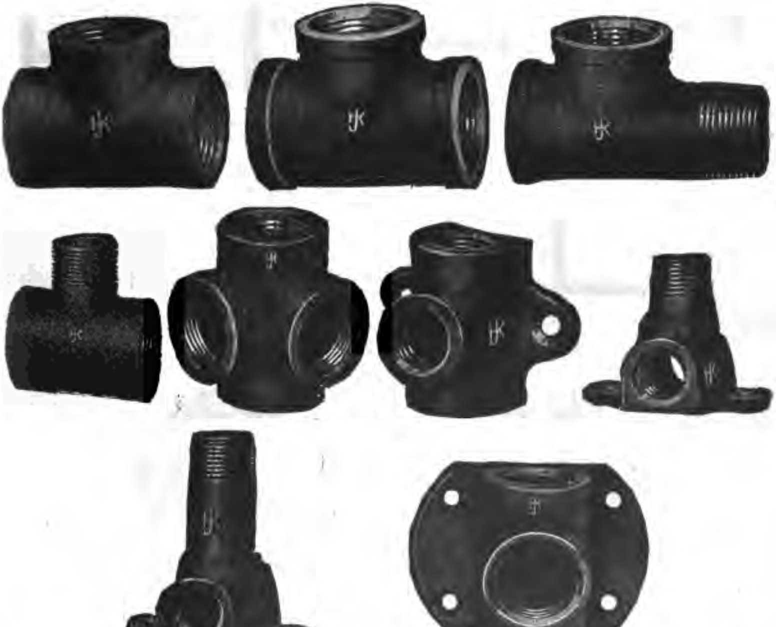
FIGS. 5,123 to 5,126.—Jarecki cast iron branch tees or headers.

Side and Back Outlet Return Bends

Size	¾	1	1¼	1½	2	2½	3
Center to center, close..........	1½	1⅝	2¼	2½	3	3⅞	4½
Center to center, open..........	2	2⅜	3⅛	3¼	4	4⅞	6¼

Tees.—These are the most important and widely used of the branching fittings. Tees, like elbows, are made in a multiplicity of size and pattern. They are used for making a branch at 90° to the main pipe, and always have the branch at right angles.

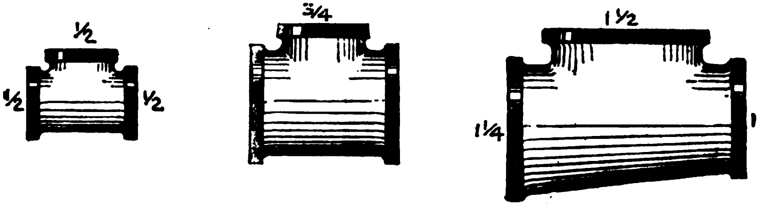
When the three outlets are of the same size, the fitting is specified by the size of the pipe, as a ½-in. tee; when the branch is of different size than the run outlets, the size of the run is given first as a 1×¼ tee; when all three outlets are of different sizes, they are all specified, giving the sizes of the run first as a 1¼×1×1½ tee.



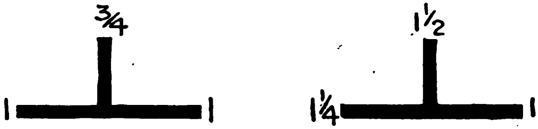
FIGS. 5,127 to 5,135.—Bernard-Greenwood malleable tees. Fig. 5,127, plain tee; fig. 5,128, flat band tee; fig. 5,129, service tee; fig. 5,130, male outlet tee; fig. 5,131, four-way or side outlet tee; fig. 5,132, female drop tee; fig. 5,133, male and female drop tee; fig. 5,134, male and female drop tee, long, with 2½ ins. drop; fig. 5,135, round flange drop tee.

This method of specifying tees is illustrated in figs. 5,136 to 5,138. It is well, however, to avoid mistakes in ordering tees not having all outlets of the same size to make diagrams with dimensions as in figs. 5,139 and 5,140. These variations give rise to a great multiplicity of patterns, of which

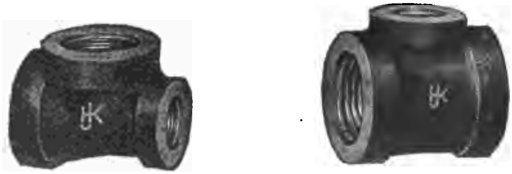
183 are listed in one catalogue for sizes, ranging from ⅛ to 6 inch. It should be noted, however, that *the number of patterns usually carried in stock is very small*, hence it is not advisable in general to specify unusual sizes.



Figs. 5,136 to 5,138.—System of specifying tees. Fig. 5,136, all outlets the same size, simply give size of pipe; fig. 5,137, branch different size than run, specify run first, thus 1×¾, fig. 5,138, all outlets different size, specify all outlets, run first, thus 1¼×1×1½.



Figs. 5,139 and 5,140.—Method of specifying tees to avoid possibility of mistakes. In ordering fittings, simply make a conventional diagram of a tee and put down the dimensions desired.



Figs. 5,141 and 5,142.—Bernard-Greenwood cast iron ***reducing*** tees. Fig. 5,141, reducing on run; fig. 5,142, reducing on side outlet.

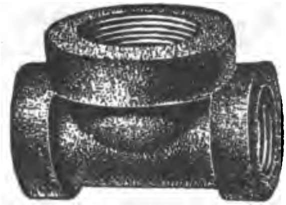
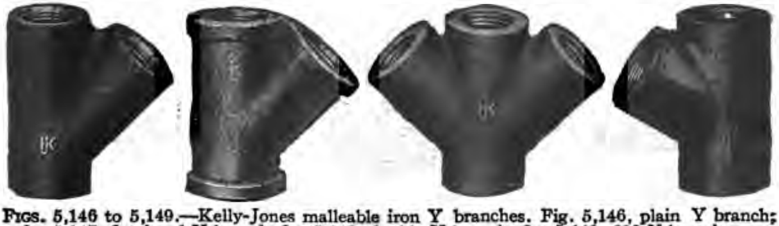


Fig. 5,143.—Cast iron ***enlarging*** or "bull head" tee, enlarging on side outlet.

Figs. 5,127 to 5,135 show various tees illustrating the great variety of patterns in use.

Y Branches.—These are similar to a tee, but have the side outlet set at an angle of 45° or 60° instead of 90°. Figs. 5,146 to 5,149 show four styles of malleable iron Y branch. The single 45° Y branches, straight and reducing, are regularly made in sizes ranging from ½ to 4 ins.; the double 45° Y branch, in sizes ranging from ½ to 2 inclusive, and the double 60° pattern in the 2-in. and 2×1½ in. sizes.

FIGS. 5,144 and 5,145.—Crane cast iron ***eccentric reducing*** tees. Fig. 5,144, eccentric outlet in run; fig. 5,145, eccentric outlet in side. The object of these fittings is to prevent lodging places for water, which condition obtains where double reducing fittings are used. When ordering eccentric tees, it is well to guard against mistakes by sending a sketch showing the exact position in which the fitting is to be placed.



FIGS. 5,146 to 5,149.—Kelly-Jones malleable iron Y branches. Fig. 5,146, plain Y branch; fig. 5,147, flat band Y branch; fig. 5,148, double Y branch; fig. 5,149, 60° Y branch.

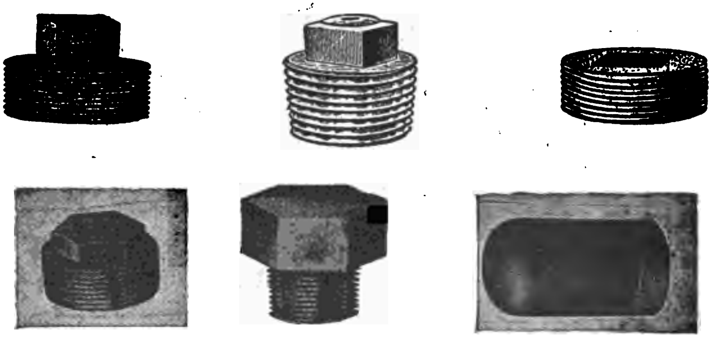
Crosses.—A cross is simply an ordinary tee having a back outlet opposite the branch outlet. The axes of the four outlets are in the same place and at right angles to each other. Crosses like tees are made in a multiplicity of sizes.

Regarding it as a tee with a back outlet, the tee part is made in various combinations of sizes, similar to ordinary tees, but the back outlet is always the same size as the opposite outlet, or side outlet, of the tee part.

5. *Shut off or Closing Fittings*

Plugs.—For closing the end of a pipe or a fitting having a female thread, a plug is used. Plugs are made of cast iron, malleable iron, and brass.

FIGS. 5,150 and 5,151.—Jarecki malleable iron crosses. Fig. 5,150, plain or gas pattern; fig. 5,151, flat band or steam pattern. The reinforcement sometimes takes the form of a band of circular section.



FIGS. 5,152 to 5,157.—Various plugs. Figs. 5,152 to 5,154, hollow, solid and countersunk cast iron plugs; fig. 5,155, Bernard-Greenwood hexagon head or diamond design cast iron plug; fig. 5,156, Crane special hydraulic rolled steel plug for 6,000 lbs. pressure; fig. 5,157, Jarecki bull plug made of wrought iron pipe in sizes ranging from 2 in. to 18 in. (O. D.) inclusive.

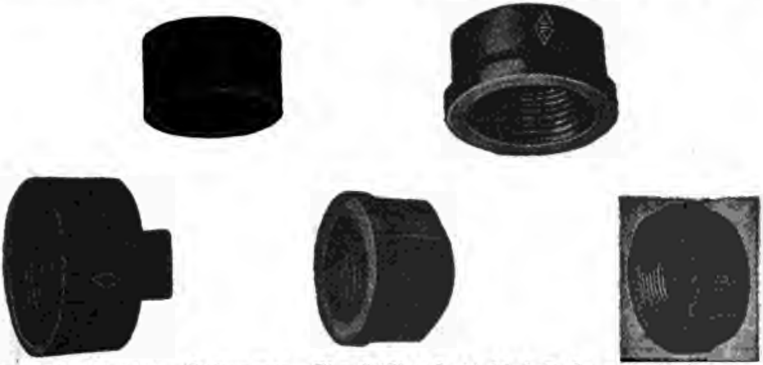
Figs. 5,152 to 5,157 show the patterns: hollow, solid, counter sunk, and diamond design.

Usually a square head or four side counter sunk is used for the small sizes, as in fig. 5,152 to 5,154, and a hexagon head for the larger sizes.

Ordinary plugs are made in sizes ranging from ⅛ to 12 ins. inclusive.

Fig. 5,156 shows a Crane special hydraulic rolled steel plug for cold water or oil working pressures up to 6,000 lbs., sizes ⅜ to 2 ins. inclusive. A special form of plug suitable for closing large openings is the bull plug shown in fig. 5,157.

Caps.—For closing the end of a pipe or fitting having a male thread, a cap is used. These, like plugs, are made of cast iron, malleable iron, and brass. Figs. 5,158 to 5,162 show various cap designs. Plain and flat band or beaded caps are regularly made in sizes from ⅛ to 6 ins. inclusive; cast iron caps from ⅜ to 15 ins. inclusive, being of plain pattern 2 ins. and smaller, and of ribbed pattern 2½ ins. and larger.

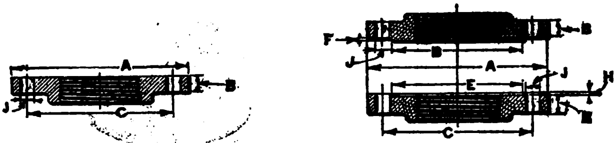


FIGS. 5,158 to 5,162.—Various caps. Figs. 5,158 to 5,161, M. I. F. Co. malleable iron caps; fig. 5,158, plain for gas or low pressure; fig. 5,159, flat band for steam; fig. 5,160, square head 1½ in. and smaller (hexagon head 2 in. and larger); fig. 5,161, drive cap; fig. 5,162, Bernard-Greenwood cast iron ribbed pattern cap.

Blind Flanges.—These (sometimes called *blank* flanges), are simply cast iron discs for closing flanged fittings or flanged pi lines. They are regularly made for all sizes of pipe from ⅜ in. up. Figs. 5,163 and 5,164 show standard brass flanges with holes drilled, and below is a table of dimensions for standard and extra heavy brass flanges.

Flanges are furnished smooth face and not drilled, unless otherwise ordered.

An important item in regard to flanges is the drilling. Standard dimensions have been adopted for the spacing, size of bolts, etc., by the American Society of Mechanical Engineers, the Master Steam and Hot Water Fitters' Association, and a committee representing the manufacturers of pipe fittings. Tables showing the dimensions adopted for standard and extra heavy cast iron flanges are given on pages 2,842 to 2,844. The above table gives the standard for brass.



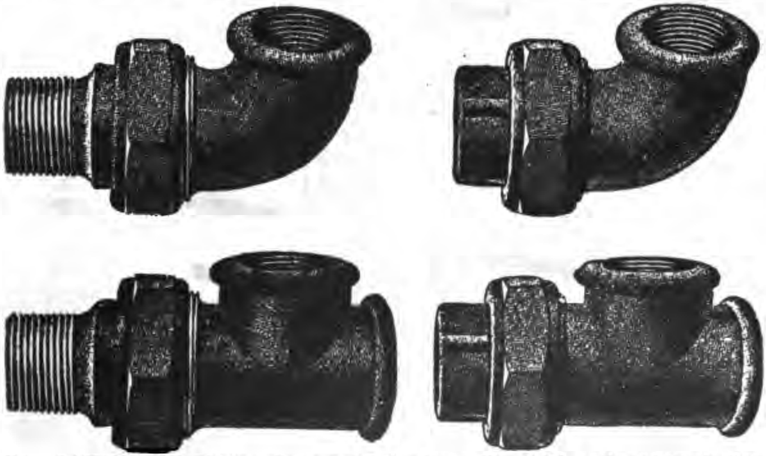
Figs. 5,163 and 5,164.—Brass flanges. Fig. 5,163, *standard* and *extra heavy* plain flange; fig 5,164, extra heavy and female flanges.

Dimensions of Standard and Extra Heavy Brass Flanges

				⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8
	Size of Pipe		inches	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8
A	Diameter of Flange	Standard	inches	2½	3	3½	4	4½	5	6	7	7½	8½	9	9¼	10	11	12½	13½
		Extra Heavy	inches	2½	3	3½	4	4½	5	6	7	7½	8½	9	9¼	10	11	12½	13½
B	Thickness of Flange	Standard	inches	5/16	11/32	⅜	13/32	7/16	15/32	½	9/16	19/32	⅝	21/32	11/16	23/32	25/32	27/32	29/32
		Extra Heavy	inches	11/32	11/32	7/16	½	17/32	9/16	⅝	11/16	23/32	25/32	13/16	27/32	29/32	31/32	1 1/16	1⅛
C	Diameter of Bolt Circle	Standard	inches	1 11/16	2¼	2½	3	3⅜	3⅞	4¾	5½	6	7	7½	7¾	8½	9½	10¼	11¾
		Extra Heavy	inches	1 11/16	2¼	2½	2¾	3⅜	3⅞	4¾	5½	6	7	7½	7¾	8½	9½	10¼	11¾
D	Diameter of Male		inches	1⅛	1 5/16	1 11/16	2 1/16	2 13/16	3 1/16	3 11/16	4 11/16	4 15/16	6 1/16	6 11/16	6 13/16	7 15/16	8 13/16	9 11/16	10 11/16
E	Diameter of Female		inches	1 3/16	1 11/32	1⅞	2 3/16	2 13/16	3 3/16	3⅞	4½	5	6⅛	6½	6¾	7⅝	8½	9 11/16	10½
F	Height of Male		inches	3/16	3/16	3/16	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	5/16	5/16
H	Depth of Female		inches	3/16	3/16	3/16	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	5/16	5/16
J	Diameter of Bolt Holes	Standard	inches	7/16	7/16	7/16	½	½	9/16	11/16	11/16	11/16	11/16	11/16	11/16	11/16	13/16	11/16	11/16
		Extra Heavy	inches	7/16	7/16	½	9/16	9/16	9/16	11/16	11/16	11/16	11/16	11/16	11/16	13/16	11/16	11/16	11/16
	Diameter of Bolts	Standard	inch	⅜	⅜	⅜	7/16	7/16	½	⅝	⅝	⅝	⅝	⅝	¼	⅝	¾	⅝	¾
		Extra Heavy	inch	⅜	⅜	7/16	½	½	½	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝	⅝
	Length of Bolts	Standard	inches	1¼	1¼	1¼	1½	1½	1½	1¾	1¾	1¾	2	2¼	2¼	2¼	2½	2½	2¾
		Extra Heavy	inches	1⅜	1⅜	1½	1½	1½	1¾	2	2¼	2¼	2¼	2¼	2½	2¾	2¾	3	3¼
	Number of Bolts	Standard	inches	4	4	4	4	4	4	4	4	4	4	4	8	8	8	8	8
		Extra Heavy	inches	4	4	4	4	4	4	4	4	4	8	8	8	8	12	12	12

6. Union or Make-up Fittings

Union Elbows and Union Tees.—The frequent use of unions in pipe lines is desirable for convenience in case of repairs. Where the union is combined with a fitting, the advantage of a union is obtained with only one threaded joint instead of two, as in the case of a separate union. A disadvantage of union fittings is that they are not as a rule so easily obtainable as ordinary fittings. Figs. 5,165 to 5,168 show union elbows and union tees of the female and male and female types.



Figs. 5,165 to 5,168.—Union elbows and union tees. Fig. 5,165, male and female elbows fig. 5,166, female elbow; fig. 5,167, male and female tee; fig. 5,168, female tee. Male and female elbows and tees are sometimes designated as male.

3. PIPE FITTING

The term "pipe fitting" includes the operations which must be performed in installing a pipe system as made up of pipe and fittings. These operations consist of:

1. Pipe cutting.
2. Pipe threading.
3. Pipe tapping.
4. Pipe bending.
5. Assembling.

The mechanic who performs the work of pipe fitting is called a *pipe fitter*, and sometimes a *steam fitter*, because the work is largely connected with steam installation. Considerable experience is necessary to become a good pipe fitter, and there are a good many persons engaged in this occupation who do not deserve the title of steam fitter.

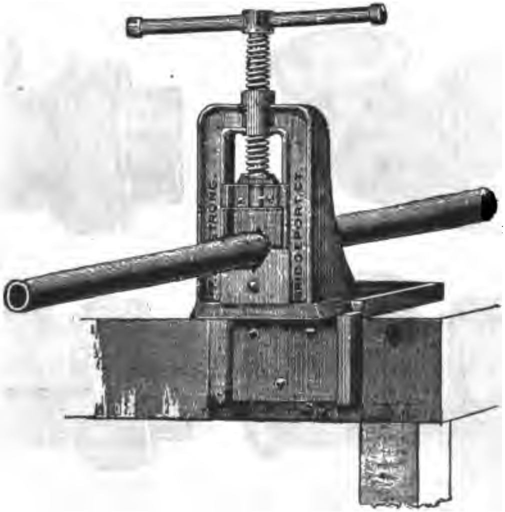
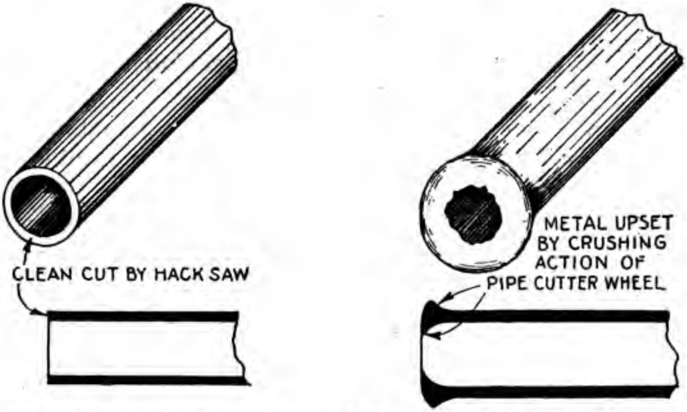


FIG. 5,169.—Ordinary pipe vise. ***It consists of*** a plain (as shown), or hinged U-shape piece containing the clamp screw, the sides of which form guides for the upper jaws. The upper and lower jaws are provided with a series of rectangular teeth as shown. When the U piece is closed over the pipe, pin inserted, the teeth of both jaws are brought in firm contact with the pipe by screwing down the upper jaw thus holding the pipe firmly.

Pipe Cutting.—Wrought pipe as received from the manufacturer, comes in lengths varying from 12 to 22 feet, and in "pipe fitting" it is frequently necessary to cut it to any particular length that may be required. This may be done with a hack saw or a pipe cutter, the pipe in either case being put in a pipe vise, as shown in fig. 5,169.

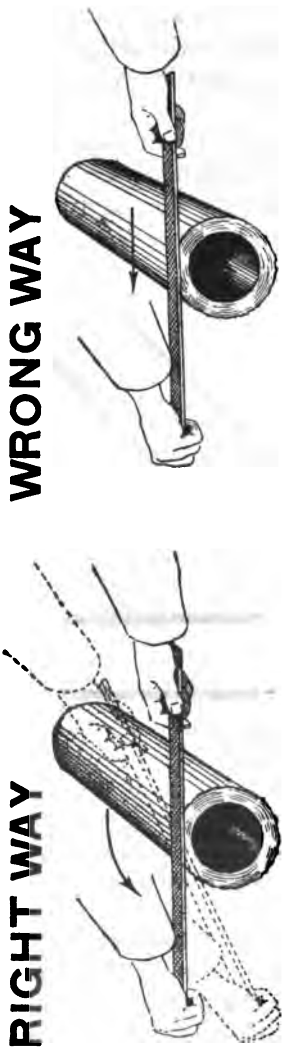
In securing the pipe in the vise, care should be taken (especially when threading) that the jaws hold the pipe sufficiently firmly to prevent slipping, but the clamp screw should not be turned enough to cause the jaw teeth to unduly dig into the pipe.



Figs. 5,170 to 5,173.—Appearance of pipe end when cut by pipe cutter, and by hack saw. When a pipe cutter is used the external enlargement of the pipe end must be removed by a file, and the internal burr by a pipe reamer, as shown in figs. 5,174 and 5,176.

A pipe cutter may be defined as an instrument usually consisting of a hook shaped frame on whose stem a slide can be moved by a screw. On the slide and frame several cutting discs or "wheels" are mounted and forced into the metal as the whole appliance is rotated about the pipe.

The operation of cutting a pipe can be done quicker with a pipe cutter than a hack saw, and for this reason the former is more frequently used, although it crushes the metal and leaves a shoulder on the outside and a burr on the inside of the pipe



FIGS. 5,174 and 5,175.—***Right*** and ***wrong*** **way of removing the shoulder left on pipe end after cutting with a pipe cutter. Obviously at each stroke, the file should be given a turning motion as indicated by the arrow and dotted position in figure 5,174, removing the excess metal through an arc of the circumference. The position of pipe is changed in the vise from time to time, till the excess metal is removed all around the pipe. When the operation is done, as in fig. 5,175, by moving the file in a straight line, it will result in a series of flat places.**

This does not apply to the knife type of pipe cutter. The appearance of the cuts made with hack saw and pipe cutter is shown in figs. 5,170 to 5,173.

The external shoulder must be removed to allow the pipe to enter the threading tool so no worry need be given that the workman will not do this, but *it should be ascertained* ***by inspection*** *that the internal burr is removed on every cut*, especially on plumbing jobs, to avoid future trouble with clogged pipes.

Too much attention cannot be given to this because the burr usually has a ragged and sharp edge, which catches any sediment or other foreign matter passing through the pipe and finally stops the flow. It must be evident also that at the outset the burrs reduce the sectional area of the pipe and thus increase the friction to flow. The proper and convenient way to remove a burr is by a brace and burring reamer, as shown in fig. 5,176.

Pipe cutters may be classed as: 1. Wheel.

2. Combined roller and wheel.
3. Knife.

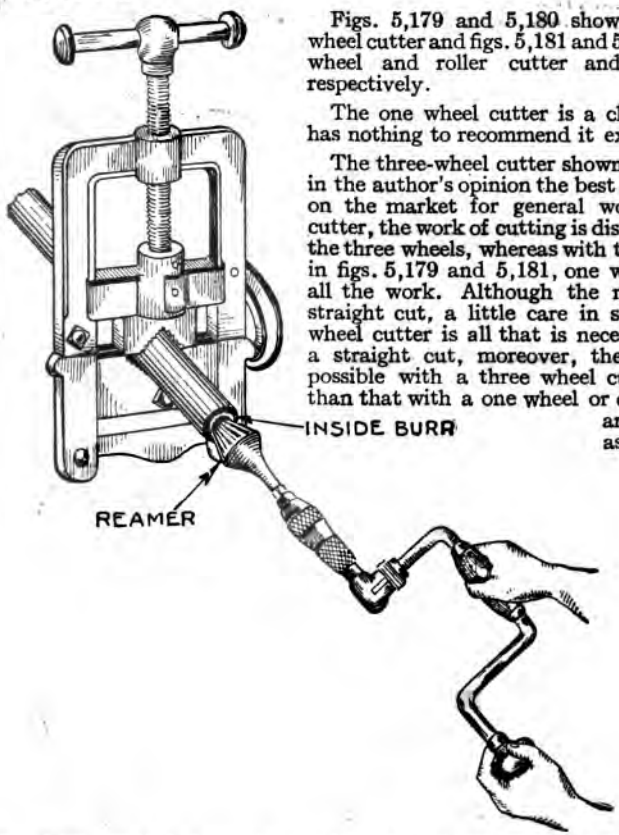


FIG. 5,176.—Method of removing burr from pipe end with brace and a burring reamer.

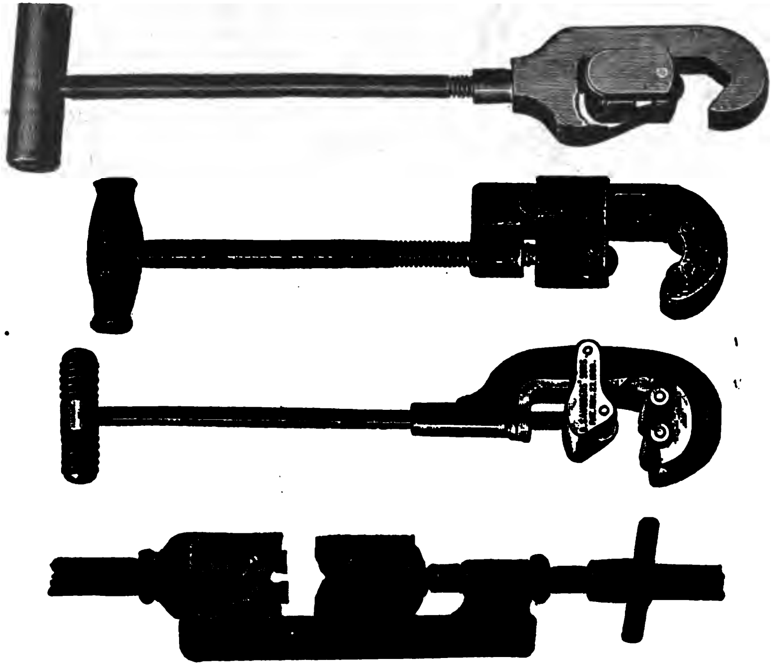
Figs. 5,179 and 5,180 show two types of wheel cutter and figs. 5,181 and 5,182, combined wheel and roller cutter and knife cutter respectively.

The one wheel cutter is a cheap affair and has nothing to recommend it except the price.

The three-wheel cutter shown in fig. 5,180 is in the author's opinion the best designed cutter on the market for general work. With this cutter, the work of cutting is distributed among the three wheels, whereas with the forms shown in figs. 5,179 and 5,181, one wheel has to do all the work. Although the rollers insure a straight cut, a little care in starting a three wheel cutter is all that is necessary to obtain a straight cut, moreover, the *range* of work possible with a three wheel cutter is greater than that with a one wheel or combined roller and wheel cutter, as illustrated in fig. 5,182. When the wheels become dull or nicked they are easily removed and renewed at nominal expense.

The knife cutter makes a clean cut like a hack saw but is a more expensive tool than the other types.

Figs. 5,177 to 5,178.—Various burring reamers for removing burrs from pipe ends after cutting. Fig. 5,177, Hall patent reamer; fig. 5178, reamer for use with brace.

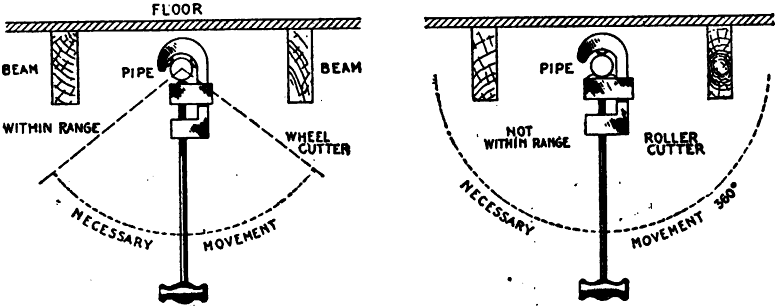


Figs. 5,179 to 5,182.—Various pipe cutters. Fig. 5,179, one wheel cutter; fig. 5,180, Barnes three wheel cutter; fig. 5,181 combination wheel and roller cutter; fig. 5,182, Beaver square end knife cutter.

Pipe Threading.—Having cut the pipe to proper length, filed off the outer shoulder and reamed out the burr, it is now ready for the threading operation. The Briggs threads may be cut on the pipe ends for screwing into the fittings either by means of

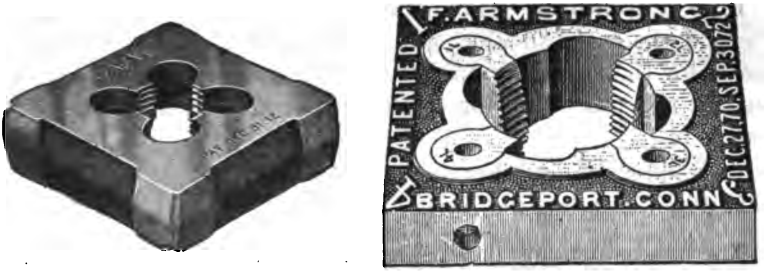
1. Hand stock and dies, or
2. Pipe threading machines.

The hand stock and dies being portable, are generally used for small jobs, especially for threading pipe of the smaller sizes, although there are some geared forms suitable for large work without undue physical effort; the threading machines are for use in shops where a large amount of threading is done. Hand stock and dies may be classed with respect to the dies, as

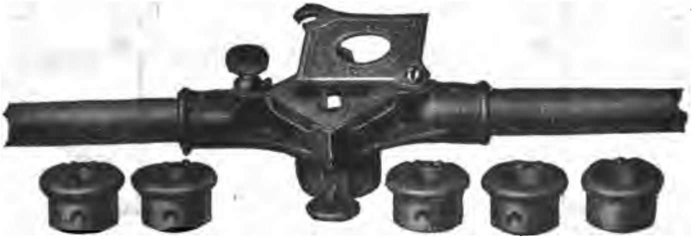


FIGS. 5,183 and 5,184.—Three wheel cutter and combined wheel and roller cutters illustrating *range*. The cuts show the comparative movements necessary with the two types of cutter to perform their functions. The three wheel cutter requiring only a small arc of movement, will cut a pipe in an inaccessible place as shown, which with a roller cutter would be impossible. Accordingly, the wheel cutter is said to have a greater *range* than the roller cutter and is therefore to be preferred for general work.

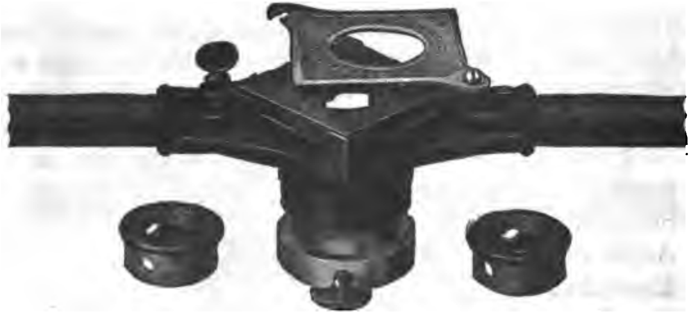
1. Solid.
2. Sectional.
3. Adjustable.
4. Expanding.
5. Receding.



Figs. 5,185 and 5,186.—Two forms of square non-adjustable pipe die. Fig. 5,185, solid; fig. 5,186, sectional.



Figs. 5,187 to 5,192.—Walworth plain pipe stock (*without leader screw*) solid die and bushings.



Figs. 5,193 to 5,195.—Walworth plain pipe stock (*with leader screw*) solid die and bushings.

type. Fig. 5,196 shows a set with single ended dies and figs. 5,197 to 5,199, the double ended die pattern. The dies are placed in them and are adjusted to the variations in the size of fittings by the set screws at the

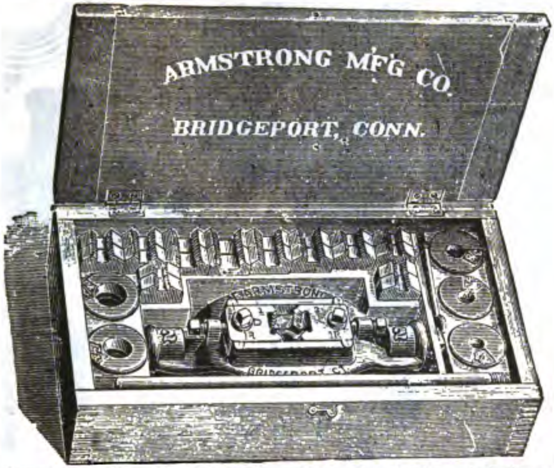
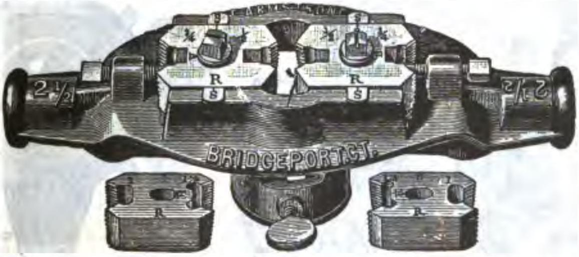
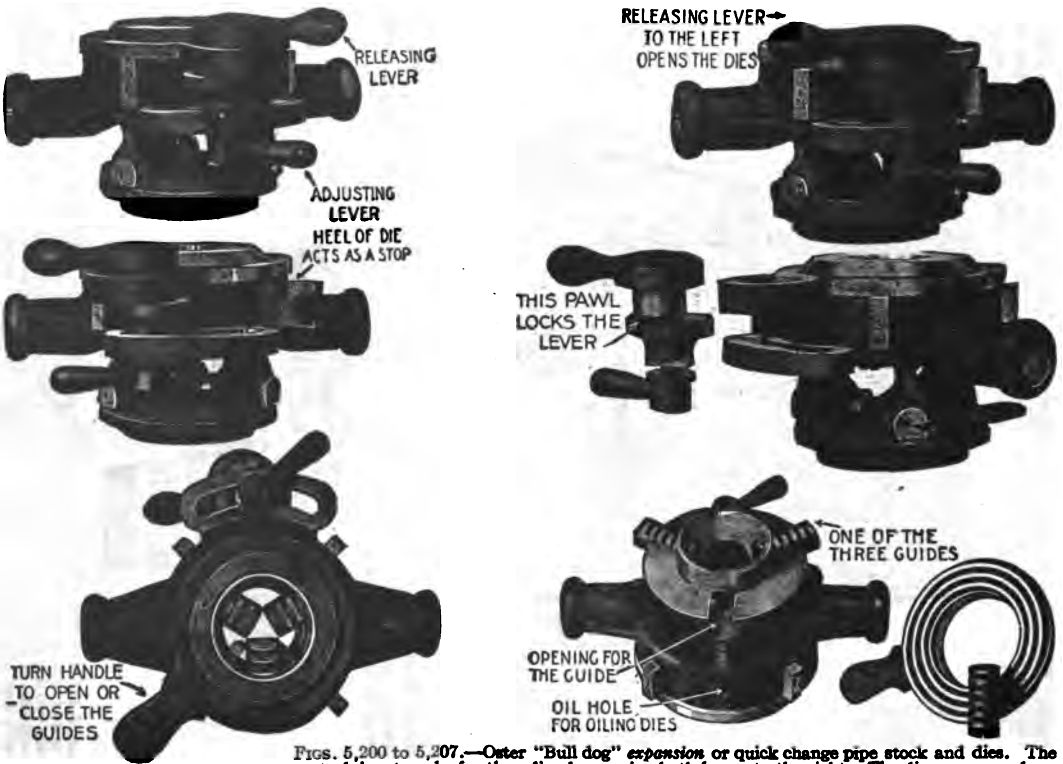


FIG. 5,196.—Armstrong *adjustable* pipe stock and dies for *single* ended dies. The dies are interchangeable in the stocks, and, although adjustable, do not need adjusting to cut the standard size for which the dies are made. The adjusting is only done when the irregularity or variations in the fitting make it necessary. There are corresponding marks $\binom{S}{I}$ on the stock and on the dies $\binom{I}{S}$ and when these marks are brought into line the dies will cut the standard size. The No. 2 set shown above can, by purchasing extra dies and bushings, be used also to thread bolts and brass tubing or fine thread dies.



FIGS. 5,197 to 5,199.—Armstrong *adjustable* pipe stock and dies for **double** ended dies. Each pair of dies, as shown, have one size thread at one end and another size at the other. Thus the two dies in the stock are in position for cutting ½-inch thread and by reversing them they will cut ¾-inch thread. The cut shows plainly the reference marks which must register with each other in adjusting the dies by means of the end set screws to standard size.


RELEASING LEVER
ADJUSTING LEVER
HEEL OF DIE ACTS AS A STOP
TURN HANDLE TO OPEN OR CLOSE THE GUIDES
RELEASING LEVER TO THE LEFT OPENS THE DIES
THIS PAWL LOCKS THE LEVER
ONE OF THE THREE GUIDES
OPENING FOR THE GUIDE
OIL HOLE FOR OILING DIES

FIGS. 5,200 to 5,207.—**Oster "Bull dog" *expansion* or quick change pipe stock and dies. The stock is set ready for threading by moving both levers to the right. The dies are opened, or** ends and secured by the bolts which pass through the dies, the holes in the dies being sufficiently larger than the bolts to allow the necessary lateral adjustment movement.

The term ***expanding*** is used to represent that class of threader in which one set of dies is used for all sizes of pipe having the same number of threads, the dies being moved closer or farther apart by means of cams or equivalent. Since only five different thread pitches are used in the entire range of pipe sizes, the advantage of this in adapting a stock for quick change is apparent. The following table shows the range of sizes for each thread:

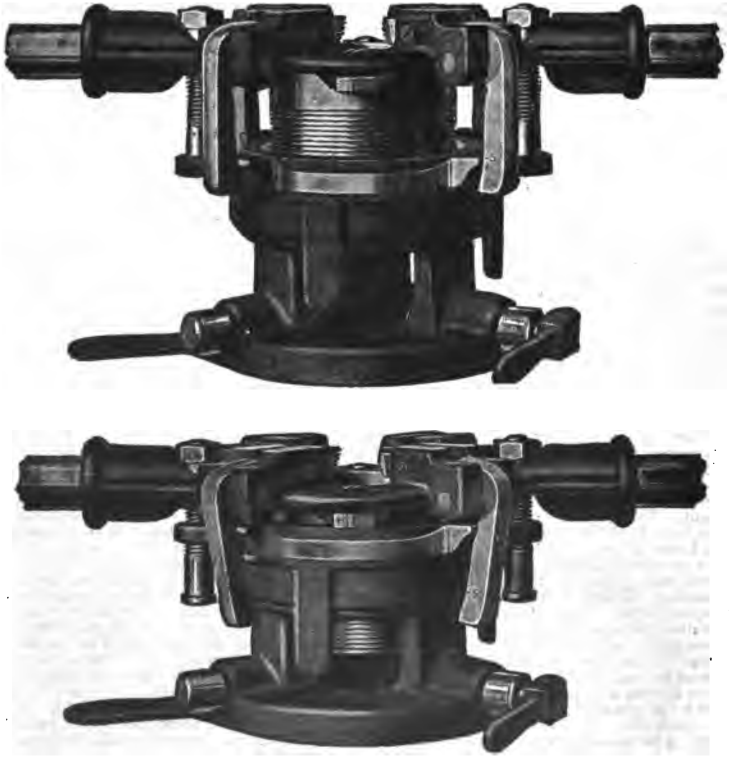
Number of threads per in.	Pipe sizes ins.
27	⅛
18	¼, ⅜
14	½, ¾
11½	1, 1¼, 1½, 2
8	2½ and above.

From the table it is seen that with two sets of dies cutting 18 and 14 threads, four pipe sizes (¼, ⅜, ½ and ¾), can be threaded, and with a set cutting 11½ threads 1, 1¼, 1½ and 2 in. pipe can be threaded. All that is necessary is to provide the stock with mechanism for quickly and properly spacing the dies to correspond with the different pipe sizes. A stock having these features is shown in figs. 5,200 to 5,207.

FIGS. 5,200 to 5,207.—*Text continued.*

closed by one movement of the releasing lever. The dies are changed from one size to another; or set for over or under size, by movement of the adjusting lever. The size is determined by the dies and the graduated marks on the face of the tool. The face of the stock is entirely free of gauges to regulate the size; or friction devices to hold the dies. In fig. 5,200, the releasing lever is thrown to the extreme left, this throw expands the dies so they will clear the thread and the stock can be lifted off without backing over the finished thread. The dies are reset to size, ***without looking at the marks,*** by simply bringing this lever back to the extreme right. ***Note that the lower adjusting lever is not touched.*** The lower lever is the lock nut, or adjusting lever, used in locking the die cam. This lever is moved along the slot until the graduated marks on the face of the tool show the desired size. Then one turn of the adjusting lever to the right will hold the dies secure while threading. This lock nut is used only when changing from one *size* to another, or when *changing the dies*. Fig. 5,201 shows both levers moved to the left to the limit of travel. The dies are now released and can be removed outward through the stock; they are here shown partly withdrawn. They will enter the stock in the same manner until the die strikes a stop. Then after the top lever is turned to the right, the dies are locked in the stock ready to reset to size. They cannot fall out. The heel of the die is ⅛-inch higher than the front, which acts as a stop, and brings the dies into engagement with the cam. Thus, when all are in as far as the stop will permit, all are simultaneously caught by the cam leaves. Figs. 5,202 and 5,203 show setting post and stock, setting post removed, to show pawl which locks the lever. ***The upper lever*** is the releasing lever used only to expand the dies sufficiently to free the thread without backing off. It is eccentric in form, and a spring pawl is provided which holds the lever in position. The pawl acts as a stop for the extreme right, or left position. ***The lower lever*** is the lock nut, or adjusting lever, used in locking the die cam. This lever is moved along the slot until the graduated marks on the face of the tool show the size you wish to thread. Then one turn of the adjusting lever to the right will hold the dies secure while threading. This lock nut is used only when changing from one size to another, or when changing the dies. Figs. 5,204 to 5,206 show guide mechanism; fig. 5,207 showing the scroll which operates the guide. In this view, one guide has been removed from the stock to show how the spiral screw draws these jaws up to register with the diameter of the pipe.

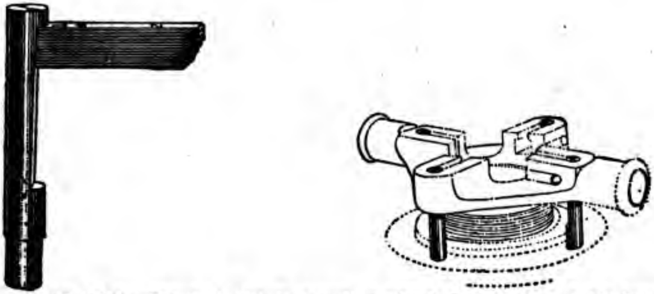
The ***receding*** form of threader employs tapered posts or levers against which the back ends of the dies rest. In cutting a thread, the dies at the beginning of the operation cut a full depth thread. As the work progresses (taking the lever type for illustration), the levers which support the dies gradually change their position, permitting the dies to ***recede*** until they



Figs. 5,208 and 5,209.—Greenfield ***receding*** pipe threader *lever form*. Fig. 5,208, position of threader when ready to thread; fig. 5,209 position of threader when cut is finished. To avoid unwinding the lead screw, three conveniently placed lugs are provided, a turn of any one of which disengages the lead screw, so that the head may be lifted or pulled straight back to original position, and reset there. The threader has a three jaw universal chuck guide. After the jaws are tightened against the pipe, one turn of the grip screw working inside of a chuck jaw completes the bite, firmly gripping the pipe. The threader is adjustable for shallow or deep threads, adjustment being made by changing the setting of the lock nut and adjusting rods that project through the head of the threader.

have finally backed completely away from the pipe. The stock can then be pulled straight off the pipe, thus avoiding unwinding or backing off.

Figs. 5,208 and 5,209 show the lever type of receding threader, and fig. 5,210 to 5,212 the tapered pin type.



FIGS. 5,210 and 5,211.—Detail of Toledo ***receding*** pipe threader; *tapered pin* form. ***In operation*** the dies are slipped into their respective slots and pushed back until they rest against the flat tapered surface of the posts. Fig. 5,210 shows one of these posts or "taper pins," and a die resting against it in proper position in the beginning of the operation of cutting a thread. During the cutting operation the die works down on these taper pins allowing the cutting teeth to recede, thus producing the tapered thread. Shallow or deep threads may be cut by varying the position of the die on the taper pins.

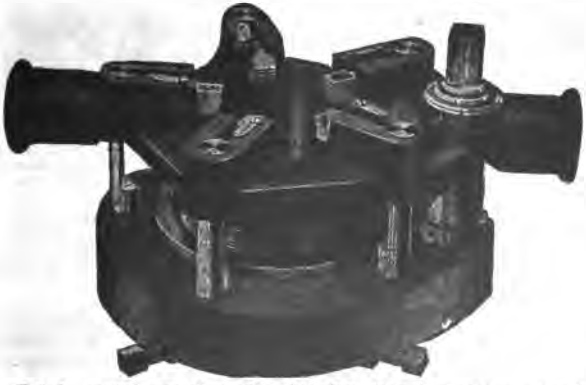
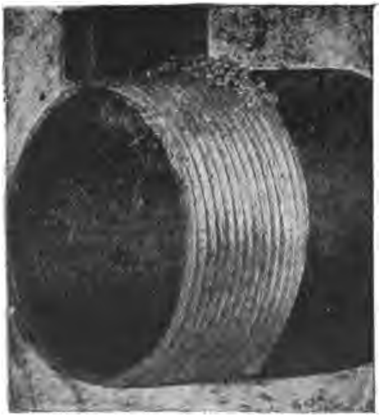


FIG. 5,212.—Toledo geared ***receding*** pipe threader; *tapered* pin form; capacity 2½ to 4 inch pipes inclusive. When the gear is used, a 4-inch pipe may be threaded (in 10 minutes as claimed) without undue effort.

Ques. Describe the proper method of cutting a thread with stock and dies.

Ans. Use plenty of oil in starting and cutting the thread. In starting press the dies firmly against the pipe end until they "take hold." After a few turns blow out the chips and apply more oil. This should be done two or three times before completing the cut. When complete blow out chips as clean as possible and back off the die. Avoid the frequent reversals usually made by most pipe fitters.



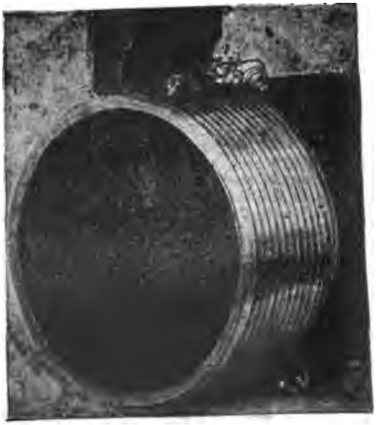


FIG. 5,213.—Thread cut with wrongly shaped but commonly used die. All pipe fitters are familiar with this pretense for a thread and no doubt wonder what makes the joint tight. The manufacturers are not to blame; they are simply trying to make their tools fool proof, as with the exception of the so called "monkey" wrench, pipe dies probably receive the greatest amount of abuse. A die having a radial cutting edge, as in fig. 5,214, does not cut but pushes the metal out, or tears it up by the roots.

FIG. 5,214.—Thread cut with properly shaped die. ***The chief points*** of a properly shaped die are: 1, correct *rake* or cutting angle obtained either by pitching the chaser above center or grinding the cutting edge; 2, sufficient *relief*, so that the cutting edge of the die will bear on the pipe; 3, enough chip clearance to avoid clogging, the lack of which often results in stuffing the thread.

For lubrication, lard will be found preferable to oil. Apply the lard to the pipe end with a brush. In cutting the thread, the heat generated will melt the lard which will flow to the cutting edge of the die giving continuous lubrication instead of spasmodic flooding as is the case when using oil.*

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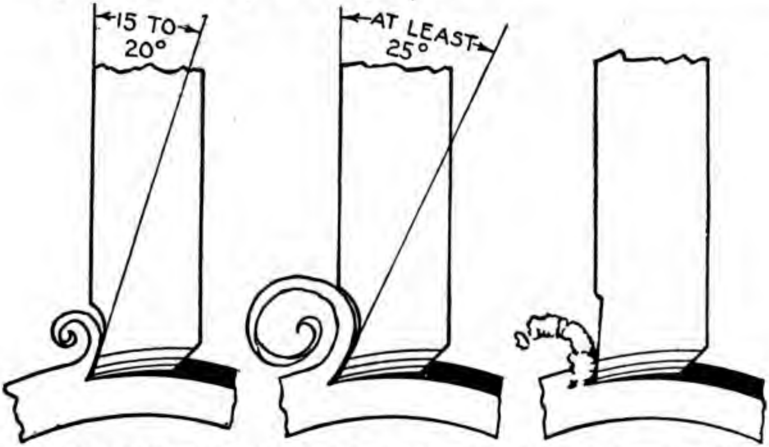
*NOTE.—The author is indebted to Mr. Harbison, thread expert of the National Tube Co., for this suggestion.

Flat Threads.—A considerable amount of material is discarded on account of the threads being a trifle flat, and such practice may be regarded as due to ignorance.

With a little reasoning it must be evident that the entire thread must be flat in order to cause a leak, and then the leak must traverse the circumference of the pipe as many times as there are threads in contact. Now it might be possible to have a leak under these circumstances if no red lead or cement were used, but with or without cement, a very small amount of perfect thread will produce a tight joint.



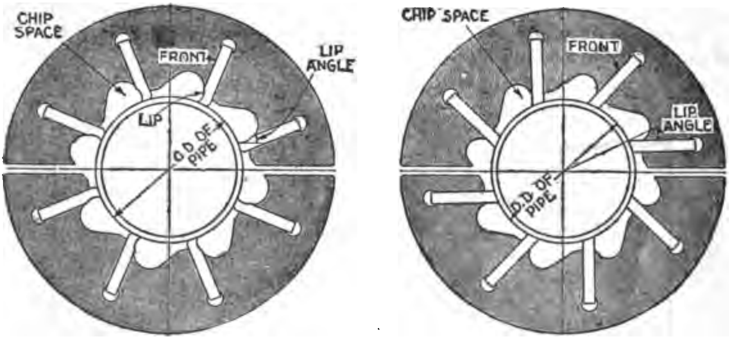
FIGS. 2,215 to 2,217.—*Lips.* Fig. 2,215 shows a chaser properly lipped for cutting ordinary steel pipe, the angle line showing how the lip should be ground. Care should be taken when sharpening the face of the chaser to maintain a good cutting angle of from 15 to 20° as shown. Grinding back the face of the chaser does no harm if properly done. Fig. 2,216 shows a die lipped for cutting open hearth steel pipe, which requires a long, easy lip on account of the tough character of material. For open hearth steel the lip angle should be 25°. Fig. 2,217 shows the ordinary form of commercial die which is unsuitable for cutting, not only steel but also wrought iron. The lip angle is insufficient. This type of chaser requires excessive power to cut the thread and the result is that the metal is pushed off instead of being cut."

Occasionally pipe is rejected on account of small grooves that sometimes occur in threads because the weld is not perfectly brought up.

A groove of this kind could not possibly produce a leak unless it ran the entire length of the thread contact, and in depth went below the bottom of the thread; such defect is, however, rarely encountered.

Pipe Threading Dies.—The greatest difficulty experienced in threading pipe is due to the use of dies which are inadequate to properly perform the work expected of them.

In order to obtain good results in threading any metal, the die must be made to *cut*—not *push*. A die which pushes the metal off instead of cutting it freely, causes the threads to break out of the die. Figs. 2,215 to 2,217 show results obtained with properly and improperly shaped dies.



Figs. 5,218 and 5,219.—**Chip space.** ***This is the space required in the die holder in front of the chaser to allow room for the chips to curl off naturally instead of accumulating.*** If insufficient space be allowed, the chips will rapidly pack in front of the chaser and will soon begin to tear the thread. Where no chip space is cut in the die ring, the chaser should project at least ¾ in., otherwise a clogging effect will be experienced. The above figures show best design for chip space; here an easy curve is provided for the chips to follow, while the back of the chaser is well supported.

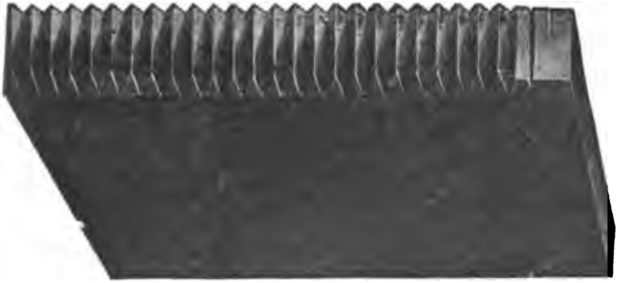
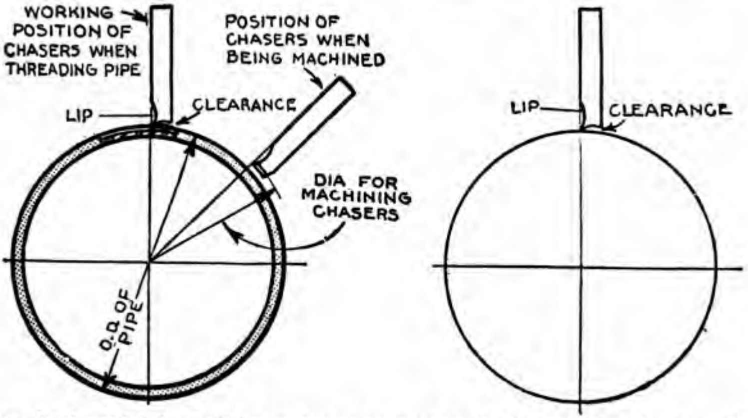
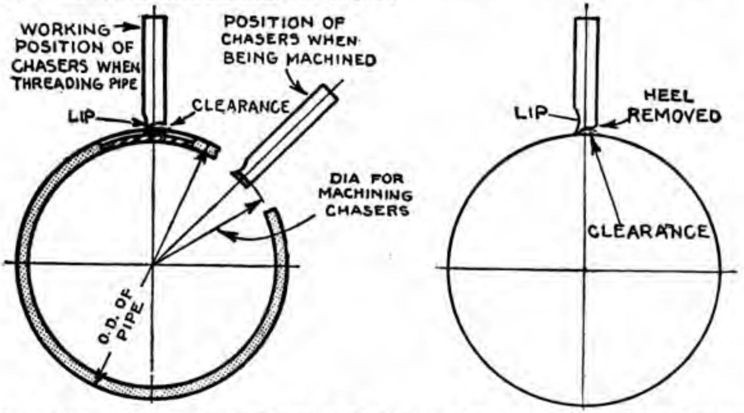


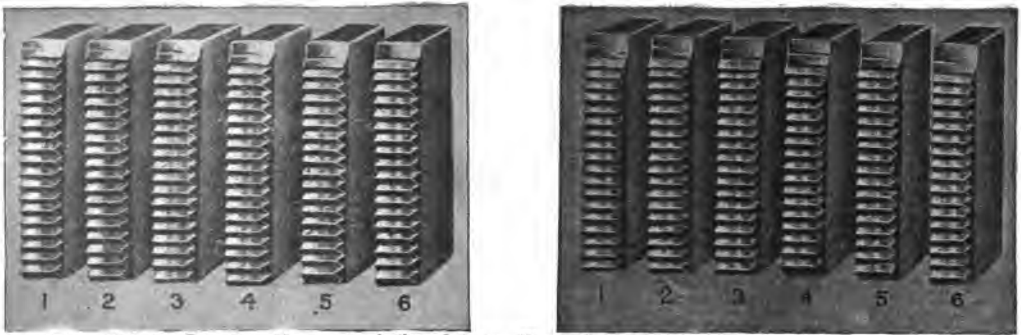
Fig. 5,220.—***Clearance.*** This is *the angle between the threads of the chasers and the threads of the pipe.* It is secured in various ways, depending upon the position in which the chasers are held in the frame. The effect of ideal clearance is shown in the figure which is from a photograph of a chaser after considerable use. When this chaser was set in the holder, the sides of the thread were uniformly dark in color, just as they were left after being hardened and tempered. When the chaser had been in use for some time the sides of the threads became polished, brighter at the cutting edge and gradually shading almost to their original color at the back. The chaser of a die which shows this condition will work freely, cut clear, will not tear the thread and will be durable. When chasers show polish from cutting edge to the back, there is a lack of clearance causing the cutting edge to work hard, heat and make a rough, torn thread.


WORKING POSITION OF CHASERS WHEN THREADING PIPE
POSITION OF CHASERS WHEN BEING MACHINED
LIP
CLEARANCE
DIA FOR MACHINING CHASERS
O.D. OF PIPE
LIP
CLEARANCE

Figs. 5,221 and 5,222.—Radial or center cut chaser and method of obtaining clearance. To ***obtain clearance*** the chasers in the machining position are *set out* larger in diameter than the size of pipe for which they are intended. Thus for a 6 inch die, the chasers would be machined to about 7/16 in. greater diameter. The effect of this is shown in an exaggerated manner in fig. 5,222, where it can be seen that the thread of the chasers (of larger diameter) gradually recedes from the thread on the pipe.


WORKING POSITION OF CHASERS WHEN THREADING PIPE
POSITION OF CHASERS WHEN BEING MACHINED
LIP
CLEARANCE
DIA FOR MACHINING CHASERS
O.D. OF PIPE
LIP
HEEL REMOVED
CLEARANCE

Figs. 5,223 and 5,224.—Advanced cut or stock on center chaser and method of obtaining clearance. The cutting edge as shown is set *ahead* of the radial line which runs through the center of the chaser. ***To obtain clearance*** the chasers in the machining position are *set in* smaller in diameter than the size of the pipe for which they are intended. With this type of die the chasers are *set in* as much as the radial cut chasers are *set out*. This is shown exaggerated in fig. 5,224 where it can be seen how the chaser thread being cut to a smaller radius recedes from the pipe thread. In this type of die the rear half or heel of the chaser should be ground off as shown, otherwise it will drag on the pipe threads and injure them.



Figs. 5,225 and 5,226.—Correct and incorrect grinding of chasers, illustrating ***lead*** or ***throat.*** Lead is the angle which is machined or ground on the front of each chaser to enable the die to start on the pipe, and also to distribute the work of making the first cut over a number of threads. The proper amount of lead is about three threads. As the heaviest cutting is done by the lead, it should have a slightly greater clearance angle than the rest of the threads on the chaser. *In the* ***correctly*** *ground* set of chasers, fig. 5,225, it will be noticed that the first or lead thread gradually increases in size from a mere scratch on No. 1, to a thread the full width on chaser No. 6. *In the* ***incorrectly*** *ground* set of chasers, fig. 5,226, this sequence of lead thread length does not obtain. The effect of this error is to unevenly distribute the work, causing the chasers which do the most work to become dull, thus making it difficult for the die to take hold when starting to cut a thread. It is the improperly ground lead which makes a die let go after being fairly well started, dulling the chaser and spoiling the thread.

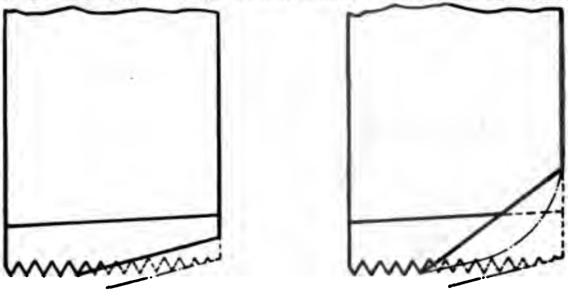


Fig. 5,227 and 5,228.—Correct and incorrect methods of grinding chasers for lead. It should be noted that if the lead in only one chaser require regrinding, the whole set must be gone over in order to make the die cut evenly. A broken tooth should always be ground out of a chaser with a thin emery wheel, as the rough portion, if allowed to remain, is likely to tear the thread on the pipe.

The manufacturers are not altogether to blame for improper design, as they are forced to shape their dies so that they may best resist the abuse they receive by improper usage.

To insure a good thread it is necessary that dies be made with a proper consideration for: lip, chip space, clearance, lead or throat, sufficient number of dies.*

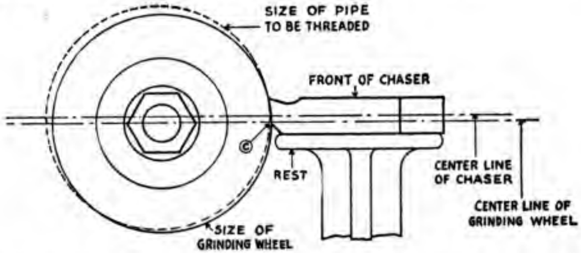
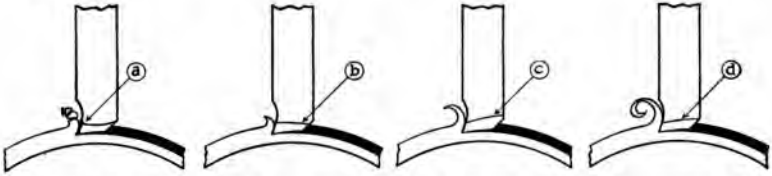


FIG. 5,229.—Proper method of grinding chasers to secure clearance in lead or throat. The chaser is raised or lowered accordingly as the design of the die requires. C, indicates the amount of clearance which will be obtained. The figure shows the approximately correct position for grinding a "stock on center" chaser to secure proper clearance on lead. The chaser in this case should be held in a perfectly horizontal position, the back of the chaser being a little below the center of the grinding wheel, which, for purpose of illustration, is shown as about the same diameter as that of the pipe. Greater clearance may be obtained by slightly raising the rest. When a grinding wheel somewhat larger than the pipe diameter is used, the center of the chaser should be slightly above the center of the wheel. The clearance may be *reduced* by lowering the rest, but the chasers should always be held horizontal unless a specially designed jig or fixture be used to hold the chaser at correct grinding angle.



FIGS. 5,230 to 5,233.—Results obtained in grinding chasers. Fig. 5,230, ***cutting edge rounded off.*** No clearance in lead. Result of careless grinding and lack of temper in steel of chaser; fig. 5,231, ***no clearance in throat or lead,*** caused by grinding the lead at too low a point on the wheel; fig. 5,232, ***too much clearance in thread or lead,*** caused by grinding at too high a position in relation to center of grinding wheel. This causes the die to chatter with resulting rough wavering thread, if not in fact stripping short pieces from the thread or breaking the chaser; fig. 5,233, ***correct throat or lead.***

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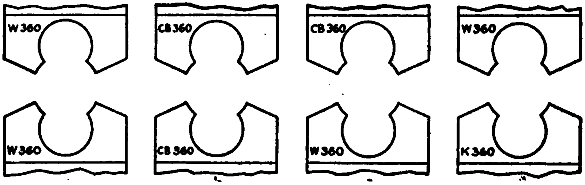
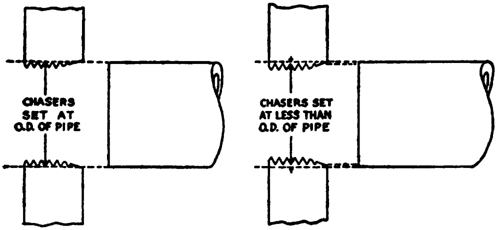
*NOTE.—All these points are taken up at length in the National Tube Co. bulletin No. 6 D on "Correct Pipe Threading Principles," and it will repay any one interested in the subject to obtain a copy of same. The author is indebted to the National Tube Co. for the accompanying cuts relating to dies and pipe threading.

Number of Chasers.—To get good results at one cut experience shows that a die should have a suitable number of chasers, the approximate number being determined by the size of the die. The experience of the National Tube Company in threading "National" pipe on power machines shows that dies up to 1¼ inches should have four chasers.

1½ in. to 4 in. should have approximately 6 chasers.
4½ " " 8 " " " " 8 "
9 " " 12 " " " " 12 "
13 " " 16 " " " " 14 "
17 " " 20 " " " " 16 "



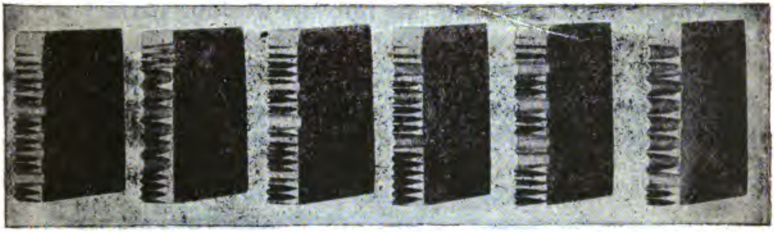
FIGS. 5,234 to 5,237.—Proper and improper selection of chasers. Figs. 5,234 and 5,235 shows two sets of chasers properly arranged in pairs according to serial number and letter; figs. 5,236 and 5,237, improper arrangement of chasers, the serial numbers of which show that the chasers belong to three different sets of dies: CB360, W360, and K360. By using chasers from two or more sets, the lead threads may not follow in proper order resulting in unsatisfactory threads. In many cases it has been found that only the *number* of a chaser has been noted and not the *serial letters*, resulting in the pipe being condemed as hard to cut and the die as being defective. In placing adjustable chasers in holder, care should be taken to set them at equal distances from the center, to avoid imperfect threads.


CHASERS SET AT O.D. OF PIPE
CHASERS SET AT LESS THAN O.D. OF PIPE

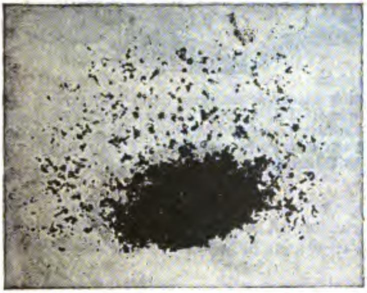
FIGS. 5,238 and 5,239.—Correct and incorrect setting of chasers with respect to depth of cut. Pipe fitters are quite apt to be satisfied that the chasers are properly set so long as the lead is sufficient to allow easy starting of the die, but it frequently happens that the chaser is set too deep and the die is literally forced on the pipe after passing the first two or three threads, resulting in stripping the top off the threads (sometimes the whole thread), overheating and ruining the die.

NOTE.—*In backing off* a solid die, where a common hand stock is used, care should be taken to see that the chaser does not jump the thread channel, causing cross threading or stripping. This is more particularly apt to happen when backing the die off the last few threads, that is, the first threads cut on the pipe.

Pipe Threading Machines.—For shop work where great quantities of pipe are threaded and especially for large work, machines are necessary. These may be either hand or power operated. They are constructed with a view of saving time and labor. Of course, with the hand machine, the time consumed in threading pipe depends upon the activity and experience of the man turning the crank.



FIGS. 5,240 to 5,245.—Effect of excessive grinding. The teeth in these chasers were ground out to illustrate that even excessive grinding at times, if properly done, does not render a chaser useless. These chasers will cut good threads, though the use of chasers in this condition is not recommended. It will be noted that there are no broken, ragged teeth to pick up stickers and tear the top off the threads. The figures also show very clearly the grinding of the heel, a precaution necessary to prevent tearing of the threads, when backing off a die that cannot be opened before removing from the pipe. Old chasers with dull and rusted threads may be resharpened with emery and oil. If too dull, they may be rehobbed. Receding dies may be rehobbed and lead reground to cut next larger size of pipe.



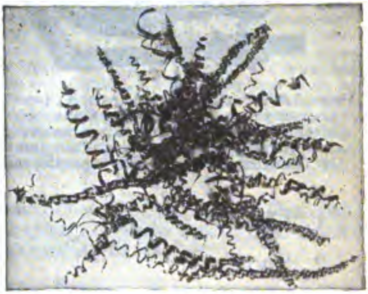
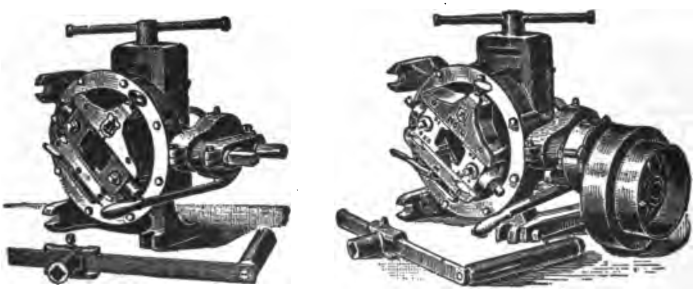


FIG. 5,246.—Appearance of chips thrown off by a chaser of incorrect shape.

FIG. 5,247.—Appearance of chips thrown off by a properly designed chaser.

As usually constructed, they are so arranged that when cutting off pipe, the dies are opened for the pipe to pass through, without being removed from the machine, by a simple motion of a hand wheel or lever, and the gears and bearings are enclosed in an oil chamber, thus keeping the bearings lubricated and preventing chips or dirt getting into the working parts.*

Nipples.—By definition a nipple is *a piece of pipe under* 12 *inches in length threaded on both ends*; pipe over 12 inches long is regarded as cut pipe. With respect to length, nipples may be classed as



Figs. 5,248 and 5,249.—Armstrong pipe threading machine showing hand and power drive. Capacity pipe ½ to 2 inches; bolts ½ to 1½ inches. The dies are adjustable and are opened after cutting thread, and, after removing pipe, return to size without resetting. Two speeds are provided for hand power; the operator can cut small pipe from ¼ to 1 inch rapidly, and by changing handle to other spindle, cut 1¼ to 2 inches, not so quickly, but easily.

1. Close;
2. Short;
3. Long;

as shown in figs. 5,038 to 5,040.

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*NOTE.—For machine cutting excellent results have been obtained with **Tonowana top** cutting oil.

The ordinary method of cutting nipples as indulged in by some plumbers and others, for lack of proper tools, is very unsatisfactory.

This consists of using a short piece of pipe with a coupling on the end as a home-made nipple holder. This is placed in the pipe vise and a piece of pipe threaded on one end screwed tightly with the coupling, and after cutting off to length desired for the nipple, an attempt is made to thread the other end. Owing to the considerable effort required to cut the thread the nipple turns in the coupling until the latter is strained to the splitting point and in fact usually does split before many nipples have been cut in this way, *resulting in profanity and a waste of time.*

In emergency, the proper way to cut a nipple with such makeshift holder so as not to split the coupling is to use adjustable dies, as, for instance, the Armstrong pattern (figs. 5,197 to 5,199). First take a very light cut, then adjust dies and take one or more additional cuts to finish. The cost of a properly made nipple holder, such as shown on page 2,840, is so small that it should be included in every pipe threading outfit.

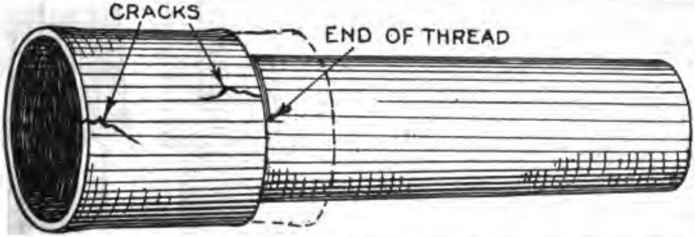


FIG. 5,250.—Makeshift nipple holder as used by some steam fitters. ***It consists of*** a short length of pipe having a coupling on one end. ***In operation,*** one end of the nipple is screwed into the coupling, and the die applied to the other end. In doing this the turning force necessary to cut the thread being considerable, the coupling will be forced on the pipe (beyond the thread) to some position indicated by the dotted line A, straining the coupling beyond its elastic limit and probably cracking same as indicated. The nipple thus made is removed from the coupling and die by the aid of a Stillson wrench and some profanity. The coupling now being in a condition known to a certain class of workmen as "*on the hog*," it is replaced by a new one each time a nipple is to be cut. ***In sending in the bill,*** the waste of time and couplings are of no consequence to an unscrupulous mechanic, for these items are charged to the customer along with such things as candles, waste, charcoal, oil, matches, etc.—at a very handsome profit.

Pipe Tapping.—Frequently in pipe fitting, it is necessary to cut internal threads on pipes, as in making pipe headers, lubricator connections, etc. This is called *tapping*, and involves 1, drilling holes to correct diameter, 2, sometimes reaming, and 3, cutting the internal threads by means of a *tap*. It is first necessary to know what size hole is required for the size of tap.

The following table gives drill sizes which permit of direct tapping without reaming the hole beforehand.

Drill Sizes for Briggs Standard Pipe Taps

(For direct tapping without reaming)

Size of pipe	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
Size of drill	21/64	7/16	9/16	45/64	29/32	1 9/64	1 31/64	1 47/64	2 13/64	2 5/8	3 1/4	3 47/64	4 15/64

Drill Sizes for Pipe Taps

Size Tap Inches	BRIGGS STANDARD		BRITISH (Whitworth) STANDARD	
	Thread	Drill	Thread	Drill
1/8	27	21/64	28	5/16
1/4	18	27/64	19	7/16
3/8	18	9/16	19	9/16
1/2	14	11/16	14	23/32
5/8	....	....	14	25/32
3/4	14	29/32	14	29/32
7/8	....	....	14	1 1/16
1	11 1/2	1 1/8	11	1 5/32
1 1/4	11 1/2	1 15/32	11	1 1/2
1 1/2	11 1/2	1 23/32	11	1 23/32
1 3/4	....	....	11	1 31/32
2	11 1/2	2 3/16	11	2 3/16
2 1/4	....	....	11	2 13/32
2 1/2	8	2 9/16	11	2 25/32
2 3/4	....	....	11	3 1/32
3	8	3 3/16	11	3 9/32
3 1/4	....	....	11	3 1/2
3 1/2	8	3 11/16	11	3 3/4
3 3/4	....	....	11	4
4	8	4 3/16	11	4 1/4
4 1/2	8	4 11/16	11	4 3/4
5	8	5 1/4	11	5 1/4
5 1/2	....	....	11	5 3/4
6	8	6 5/16	11	6 1/4
7	8	7 5/16	11	7 5/16
8	8	8 5/16	11	8 5/16
9	8	9 5/16	11	9 5/16
10	8	10 7/16	11	10 5/16

FIGS. 5,251 and 5,252.—Pipe tap and pipe reamer.

The table at the left (by Greenfield), gives drill sizes for pipe taps for both the Briggs or American Standard, and Whitworth, or British Standard.

Figs. 5,251 and 5,252 show a pipe tap and reamer; fig. 5,253 combined tap and drill reamer. Since the thread is tapered, it might be inferred that after drilling, the hole should be reamed with a tapered pipe reamer, but this is not necessary if the size of the drill be increased slightly.

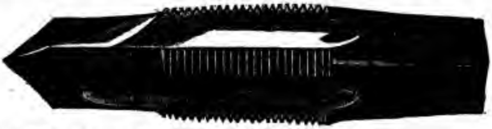


Fig. 5,253—**Pratt and Whitney combined pipe tap and drill.**

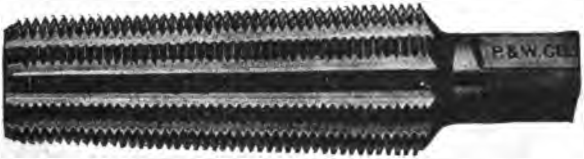
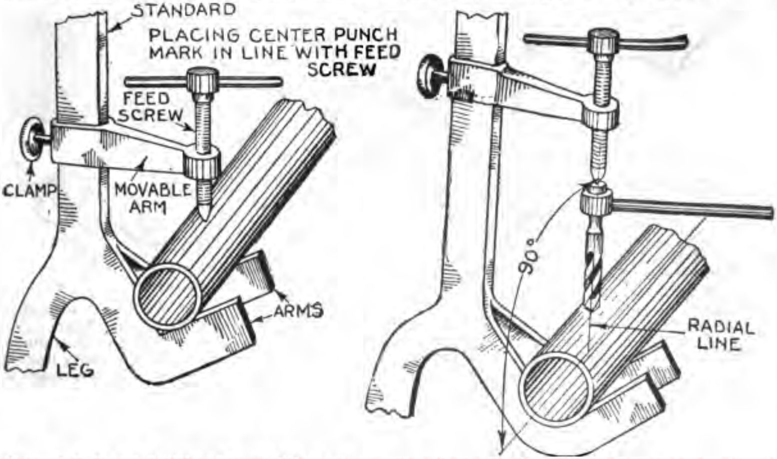


Fig. 5,254.—**Pratt and Whitney pipe hob or master tap for cutting the threads of dies.**



Figs. 5,255 and 5,256.—**Pipe drilling** crow and method of using. The crow consists of two V arms and a leg forming a tripod support for the upright rectangular post or standard. An arm is arranged to slide on the standard and is secured in any position by the clamp. At the end of the arm is tapped a feed screw with hardened point, which is directly over the line joining the apices of the V arms, hence the point of the feed screw, when lowered, will touch the surface of a pipe resting in the V arms at a point so located that the axis of the feed screw passes through the center of the pipe. Moreover, the feed screw being perpendicular to the line joining the apices of the V arms, if a drill be applied at the same point touched by the feed screw, and guided by the feed screw as in fig. 5,256, the hole will be drilled radially and at right angles to the pipe axis.

In drilling a pipe for tapping, care should be taken that the drill be guided in a radial direction and perpendicular to the pipe axis. Fig. 5,255 shows a pipe drilling crow designed for the purpose and fig. 5,260, pipe and drill in position. Of course where such device is not at hand, various makeshifts have to be resorted to.

Fig. 5,257 shows a method of holding a ratchet drill in place, the drill being aligned by square and eye. In tapping, special care should be taken not to turn the tap with too much force, especially with small taps, to avoid danger of breaking. If the tap do not turn reasonably easy, work it back and forth and occasionally back off to remove chips, and always use plenty of oil in tapping wrought pipe.

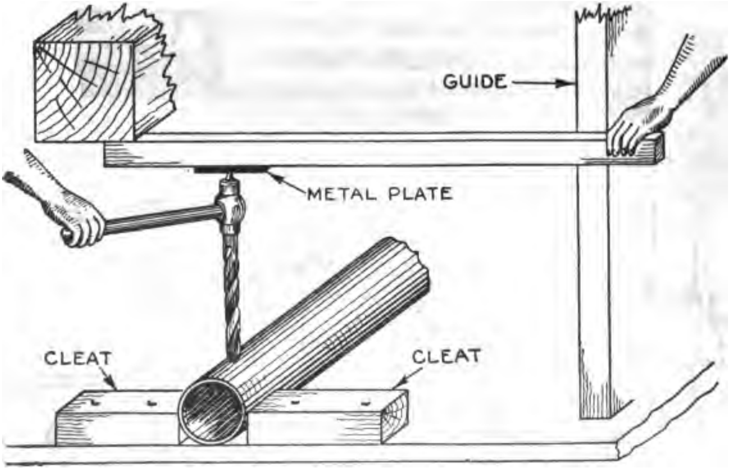
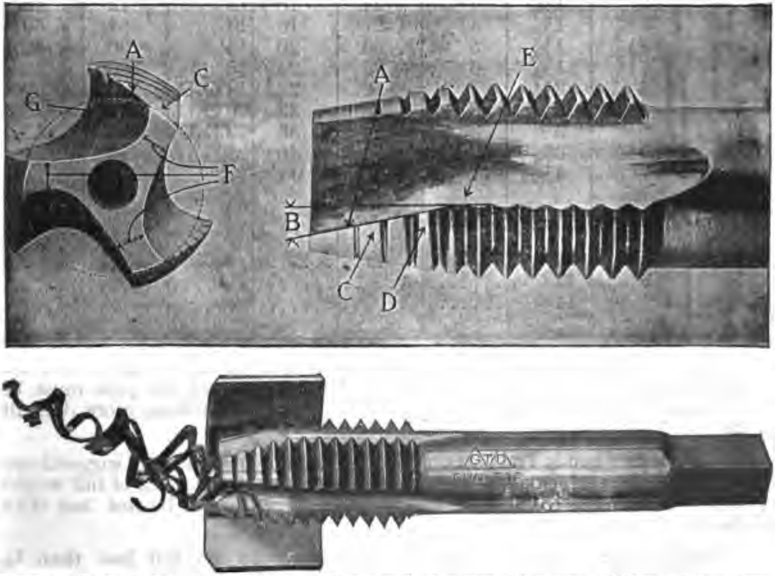


FIG. 5,257.—Ordinary method of drilling a pipe for tapping where a crow is not available. One end of a lever is placed under the edge of a timber, as shown, while a helper bears down on the other end, sliding the lever in contact with a vertical timber, using it as a guide. When this plan is adopted it is not necessary to operate the feed screw in the upper part of ratchet, as the lever follows it down. This could not be done in the case of a deep hole, as the top of drill would be carried out of place, but it is all right for drilling one or more holes in a pipe as shown.

Pipe Bending.—There are numerous instances where it is desirable to bend the pipe rather than use additional fittings to make directional changes in the pipe line. With the proper facilities pipe may be bent within certain limits without difficulty.

The following table gives the advisable and minimum radii to which standard wrought pipe may be bent.



FIGS. 5,258 to 5,260.—Greenfield "Gun" tap and character of its cut. This tap differs from ordinary taps in that the cutting edges A, are ground at an angle B, to the axis of the tap. This causes the tap to cut with a shearing motion, that is, with the least resistance to the thrust. The angle of the flutes deflects the chips so that they curl out and ahead of the tap and do not collect and break up in the flutes. This action of "shooting" the chips ahead in long unbroken coils is responsible for the name "Gun" given to the tap; fig. 5,260 shows this action, which since it is non-clogging, the tap does not have to be backed out of deep holes to clear collected chips from the flutes. ***Instructions for grinding:*** 1. See that the abrasive wheel is shaped to fit the flute at G, (fig. 5,258) in order to maintain the shape of hook exactly. 2. When the ends of the lands F, get thin from continued regrinding, grind the end of the tap straight back until lands reach normal thickness. 3. In regrinding chamfer or plugging C, be sure to grind the relief, seeing that the cutting edge A, is the highest edge; gradually backing away from this edge as shown by the circle at C. 4. The last plugged thread D, should be about two threads below the junction of the bevel and straight flute. 5. Slightly round off any corner at junction of bevel and straight flutes E, carefully. 6. Maintain this angle B, for shear cut. 7. In regrinding remove as little metal as possible—merely enough to keep the cutting edges sharp and maintain the original form.

Radii for Standard Wrought Steel Pipe Bends

(As recommended by National Tube Co.)

Pipe size inches	Center to face	Minimum radius inches	Pipe size inches	Advisable radius inches	Minimum radius inches	Pipe size inches	Advisable radius inches	Minimum radius inches
⅛	2	1¼	4	24	16	12	72	48
¼	2¼	1⅜	4½	27	18	13	84	60
⅜	2½	1½	5	30	20	14	90	68
½	3¼	1¾	6	36	24	15	100	76
¾	4	2¼	7	42	28	18 O.D.	125	90
1	4½	2½	8	48	32	20 O.D.	150	120
1¼	5	3	9	54	36	22 O.D.	165	132
1½	5¾	3¼	10	60	40	24 O.D.	180	144
2	7	4½	11	66	44	....	....	....
	Advisable radius							
2½	15	10	....	....	....	....	....	....
3	18	12	....	....	....	....	....	....
3½	21	14	....	....	....	....	....	....

The radii given in the table are as short as should be used to secure good results and if they be reduced, the thickness of the pipe must be increased. As the radius is decreased, however, it becomes more difficult to avoid buckles.

For making bends The National Tube Co. offer the following suggestions: Bends 12 ins. and smaller to regular dimensions to be made of full weight pipe. Bends 14, 15 and 16 ins. outside diameter to be not less than ⅜ in. thick.

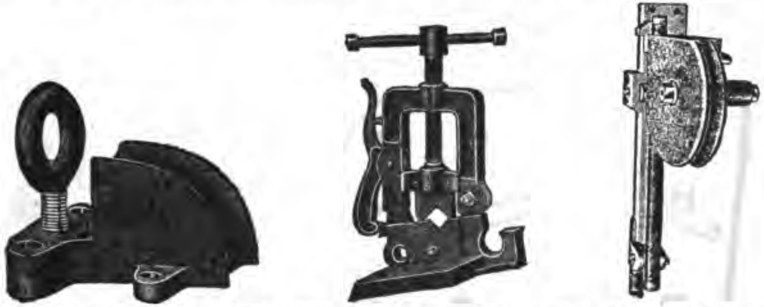
Bends 18 ins. outside diameter and larger to be not less than 7/16 ins. to ½ ins. thick.

For offset bends try to make a straight length between the bends in preference to the direct reverse bend: this is of advantage to the pipe bender.

With the welded flanges there must be a short, straight length of pipe between the bend and the flange. On sizes under 4 ins. this should equal, at least, 1½ diameters; on sizes over 4 ins. it should equal at least 1 diameter of the pipe. In all cases it is better if equal to 2 diameters of straight pipe.

Ques. How may pipes be bent by hand without the use of special tools?

Ans. *Completely* fill the pipe with dry sand and cap the ends so the filling will be retained. Heat the part to be bent; clamp the pipe in a vise as close to the part to be bent as possible. Now cool the *outside* of the curve with water so that the inside, being hot and plastic, is compressed as the bend is made.



FIGS. 5,261 to 5,263.—Pipe bending devices. Fig. 5,261, Vanderman bending form; fig. 5,262, Vanderman pipe vise with bending form combined; fig. 5,263, small pipe bending machine, suitable for ¾ to 1¼ in. pipe.

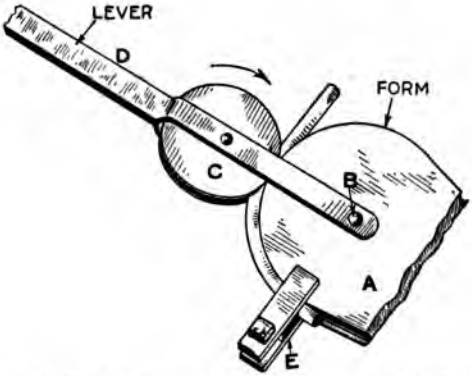


FIG. 5,264.—Common bending device consisting of a circular form **A**, with bending pulley **C**, radially hinged at **B**. Owing to the considerable effort required to bend pipe, the part **A**, must be very securely fastened to some rigid support. ***In bending*** the lever is brought over to the projection **E**, and pipe placed in position. Then the lever is forced around in the direction indicated by the arrow, thus bending the pipe to conform with the bending form. The pipe, of course, must first be filled with sand and capped to prevent buckling, and also heated if the bending radius be small enough to require heating.

The heating should be restricted to the section to be bent. It is usually necessary to heat several times in making a bend to short radius; nothing is gained by overheating. The outside of the bend is cooled with water to force the compression of the metal on the inside, which slightly reduces the volume filled by the sand and this causes the latter to give better support to the walls.

For bends over 15 times the pipe diameter the use of water for cooling the outside of the curve is not necessary.

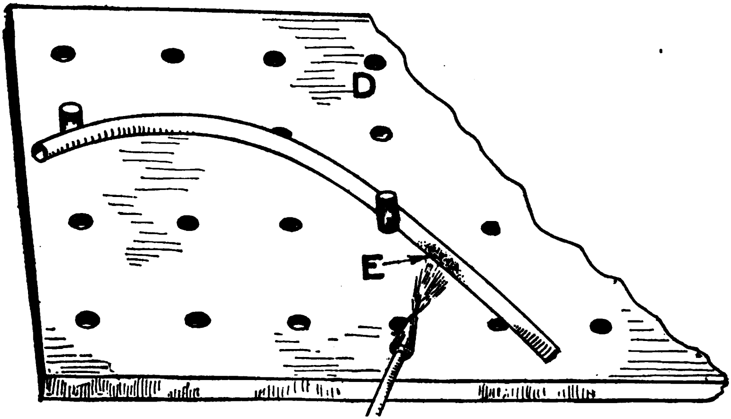


Fig. 5,265.—Bending block and pins. This is a simple method, but requires a careful workman to get a smooth job, and though adaptable to the largest sizes of pipe, may require a tedious amount of work. Two pins are required for the necessary leverage to pull the pipe around. The plate is desirable for keeping the bend in a true plane. ***In bending,*** the pipe is heated in a small spot at a time on the inside of the bend, as shown in the shaded portion at E. If the heat extend around the outside of the pipe, this should be chilled with water immediately before bending, the object being to keep the outside cold to prevent flattening the pipe while the pressure of the bending causes the inside to upset and so furnishes the shorter radius for the inside. Only a very small portion of the pipe can be heated at a time and should the pressure cause the inside to start to kink at any point, that place must be immediately chilled with water, and the bending continued further along. On account of the constant shifting of the heat on a very small portion at a time, the use of an oil torch for heating is a great advantage, as it saves carrying the pipe to and from a forge, but the latter can be used if necessary.

Ques. When the required curve has been obtained how is it retained while bending the other sections?

Ans. By cooling with water.

Pipe Bending Tools.—There are a variety of devices composing hand tools and machines for bending pipe. Fig. 5,261 shows the smallest and simplest device which is intended to be bolted to a table and is suitable for bending pipe of small sizes ranging from ⅛ to 2 ins. Fig. 5,262 shows a pipe vise with bending forms combined, and fig. 5,263 a machine suitable for pipes ¾ to 1¼ ins. Figs. 5,264 to 5,267 show some interesting tools and pipe bending methods.

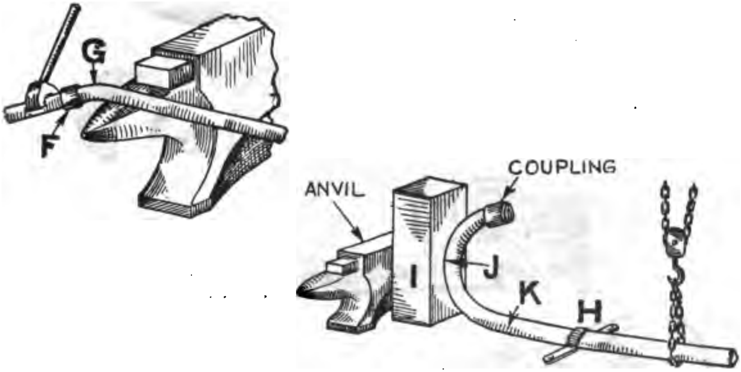
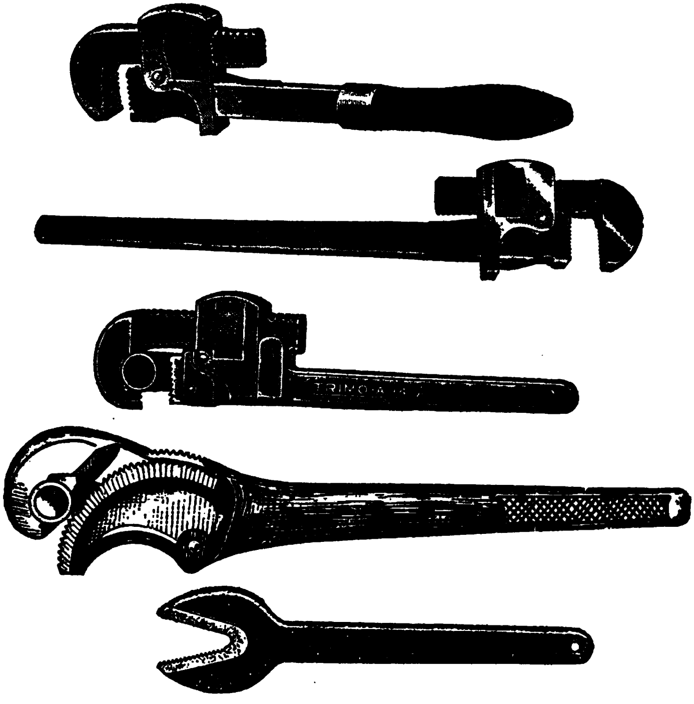
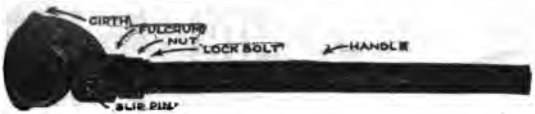


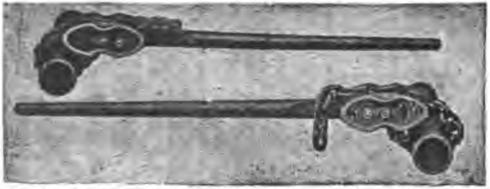
FIG. 5,266 and 5,267.—Anvil method of pipe bending. In fig. 5,265 a coupling and short length of pipe are temporarily fitted on the end at the slat, as shown at F. A short heat is taken close to the coupling at G, the pipe laid over the horn of an anvil, and with a swage and sledge the bend is started, turning the pipe over on its side if necessary to work out any kinks or flattening that may occur while this first bend is being made. The added section of pipe is then removed and a quite different method continues the work, as shown in fig. 5,267. The clamped band handle H, is now bolted on some distance back from the end, and the pipe itself is suspended by a block and sling, so that it may be easily raised and lowered as necessary, and must be hung from a support far enough above it so that it may be swung pendulum fashion through a swing of three or four feet. A heavy wood block I, for a "butting post" is leaned up against a convenient anvil or wall, as shown. A short heat is then taken on the pipe just beyond and adjoining the portion that was first bent. It is then swung like a ram against the block, and the force of the blow acting on the tangent of the first bend causes a continuation of the bending in this next section, while sufficient upsetting of the material takes place at the same time so that there is no flattening down of the outside, and the pipe holds up to its full form. This same procedure is continued for one section following another, and the pipe rolls up into forms as shown at J, where in this case the shaded portion K, indicates the place where the bending is taking place. Care must be used that the bend does not run out of a true plane, and if there be any tendency toward doing so, the work must be laid on a face plate or anvil and tuned up. In working with this method and that of fig. 5,265, the smith must work up to an inside template which has been made up for the radius of the inside of the bend, using care to keep each added bend close to the template size to save any unnecessary bending or straightening of the work later on when it might not be so easily performed without rewoking the whole piece.

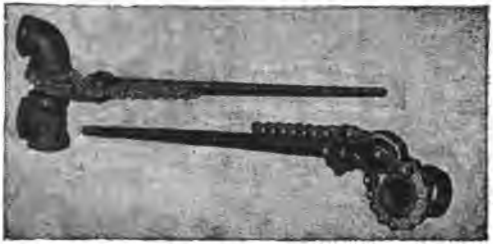
Assembling.—On large jobs the pipe is usually cut according to a sketch or working drawing and partly assembled at the shop. If no mistakes have been made in following the dimensions on the drawing, and the latter be correct, the pipe and fittings may be installed without difficulty, that is, the last joint will come together or "*make up*." This last joint is either a union, a right and left, or long screw joint, and if errors have been made in cutting the pipe, it will be difficult or impossible to make up this closing joint.



Figs. 5,268 to 5,272.—Various pipe wrenches. Fig. 5,268, Stillson with wood handle 6 to 18 ins.; fig. 5,269, Stillson with steel handle 18 ins. and larger; fig. 5,270, Trimo; fig. 5,271, Reed; fig. 5,272, Alligator.



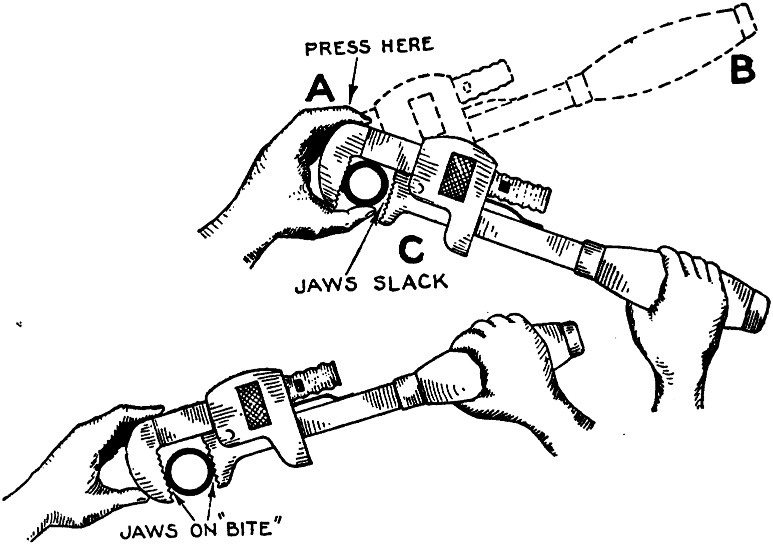




FIGS. 5,273 to 5,280.—Various pipe wrenches. Fig. 5,273, Parmelee, nut lock type; fig. 5,274, Parmelee, sleeve lock type; fig. 5,275, Warnock wrench for brass or finished pipe. ***Chain wrenches:*** Fig. 5,276, Robbins; fig. 5,277, Vulcan bi-jaw, with flat chain; fig. 5,278, Vulcan bi-jaw with cable chain; figs. 5,279 and 5,280, Agrippa.

On small jobs no sketch is necessary, the fitter proportioning the pipe lengths mostly "by eye," taking occasional measurements where necessary during the progress of the work. It should be noted that with the great variety of fittings available any pipe system may be arranged in numerous ways, and the proper selection of these fittings and general arrangement of the system so that it will be direct, simple, accessible for repairs, etc., is an index of the fitter's ability.

In making up screwed joints, red or white lead, graphite, or some standard joint cement should be used. Of these, red lead is most extensively used. It is no doubt most efficient in making a tight joint, but it is more difficult to unscrew the fitting in case of repairs than when graphite is used.



FIGS. 5,281 and 5,282.—How to use a pipe wrench. Adjust wrench so that jaws will take hold of pipe at about the middle part of the jaws. To support wrench and prevent unnecessary lost motion when wrench engages pipe, hold jaw at A, with the left hand pressing it against the pipe. At the beginning of the turning stroke B, with jaw held firmly against pipe with left hand, the wrench will at once "bite" or take hold of pipe with only the lost motion necessary to bring jaw C, in contact with the pipe.

In applying the red lead or other material *it should be put on the male thread only;* if put on the female thread, when the pipe is screwed in, some of the red lead will lodge inside the pipe and form an obstruction, especially in small pipes. A convenient method of applying red lead or cement is with an old tooth brush, as in fig. 5,283. In making up a joint it should not be screwed fast enough to produce undue heat, because the resulting expansion of the pipe will not allow a proper number of turns to be made and on cooling and contracting the joint may be loose enough to cause a leak.

The ordinary pipe fitter, when called upon to put up piping that will be subjected to a pressure of 200 to 300 lbs. of steam, feels that he is shouldering a heavy responsibility, but should be called upon to make joints that would have to bear 1,000 lbs. air pressure, he might not feel like assuming the responsibility at all. Again, if he undertake the work, probably he would feel certain that it would be necessary to resort to extraordinary means to get the desired results. No doubt he would decide that with the ordinary material manufactured and supplied to the general market, such work under these conditions was impossible. Tight joints may be easily made for 1,000 lbs. air pressure when the work is correctly done.

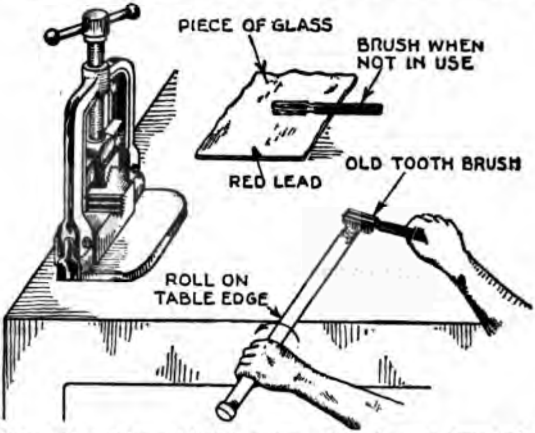
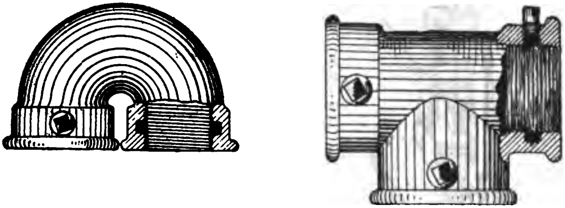


FIG. 5,283.—Method of applying red lead or other material to male thread with an old tooth brush. The pipe is rested against the bench or other support and turned by the left hand in the direction indicated by the arrow while the joint material is applied with the brush as shown. It is unnecessary to put much material on the threads, as it will be simply pushed out and wasted when the joint is screwed up. It should, however, be put on evenly and cover all the threads, care being taken not to let any touch the reamed end of the pipe where it may get inside. The red lead is preferably obtained in the powder form and mixed with oil and a little dryer at the time the pipe is to be made up. Get a clean piece of glass on which to prepare the lead. The tooth brush should be laid on the glass after applying the lead, *to avoid getting grit on the brush* and paint on the table. When grit becomes mixed with the lead it prevents close contact of the filling and pipe thus making the joint less efficient.

Ques. What is the secret of making tight joints?

Ans. 1, The threads should be clean, 2, the best lubricant should be used to prevent friction, and 3, in making up the joint it should not be screwed up fast enough to make any appreciable change in the temperature of the metal.

When these conditions obtain, the metal may be brought together as solidly as possible, which, as must be evident, is necessary to obtain a tight joint. The friction mentioned in 2 is due to the large amount of bearing surface, especially when there is grit in the threads and the metal is coming solidly together.



FIGS. 5,284 and 5,285.—Tight joint fittings. **Fig. 5,284, tight joint return bend**; fig. 5,285, tight joint tee.

NOTE.—***Pipe cement*** for iron or brass: 1 lb. No. 2 Sylvan cup grease; 35 lbs. white lead; 8 lbs. ground graphite.

NOTE.—***For grinding dies*** use Norton Alundum wheel 36-P.

NOTE.—***Foreign pipe threads.*** According to W. J. Baldwin on the practice of Germany and France (comparing the German and French systems with the Briggs system), Germany uses straight threads nearly altogether. The pitch and form of thread is about the same as the English except that the thread as a whole is not tapered. France is more irregular in practice, the Navy following one method and private shops other methods. The French Navy, however, leans toward tapered threads. South American countries have no fixed standards, but import from the United States and England and use the method of the country from which they import. Canada uses the Briggs standard. In Mexico a great deal of American pipe and fittings are used, but Mexico and the South and Central American countries use the methods of those from whom they buy as a rule.

NOTE.—***The bursting pressure*** of screwed fittings is from ten to twenty times the working pressure. The internal fluid pressure is not the determining factor, as fittings must withstand the strain of expansion, contraction, weight of piping, settling and water hammer and there is also the possibility of variation in thickness. ***For cast iron the bursting pressure is generally in excess of 1,000 lbs., and for malleable iron, it is in excess of 2,000 lbs.***

NOTE.—***A good cement*** for making tight joints in pumps, pipes, etc., is made of a mixture of 15 parts of slaked lime, 30 parts of graphite, and 40 parts of barium sulphate. The ingredients are powdered, well mixed together, and stirred up with 15 parts of boiled oil. A stiffer preparation can be made by increasing the proportions of graphite and barium sulphate to 30 and 40 parts respectively, and omitting the lime. ***Another cement*** for the same purpose consists of 15 parts of chalk and 50 of graphite, ground, washed, mixed, and reground to fine powder. To this mixture is added 20 parts of ground litharge, and the whole mixed to a stiff paste with about 15 parts of boiled oil. This last preparation possesses the advantage of remaining plastic for a long time when stored in a cool place. Finally, a good and simple mixture for tightening screw connections is made from powdered shellac dissolved in 10 per cent. ammonia. The mucinous mass is painted over the screw threads, after the latter have been thoroughly cleaned, and the fitting is screwed home. The ammonia soon volatilizes, leaving behind a mass which hardens quickly, makes a tight joint, and is impervious to hot and cold water.

Friction, as previously stated, produces heat, and heat produces expansion, hence, as the pipe is lighter than the fitting, it expands more and therefore, when both become cold, the pipe contracts more than the fitting, thus causing a tendency to leak.

Ques. Are especially long threads favorable for tight joints?

Ans. No.

According to the Crane Co., the larger the thread, the more the tendency to friction, which prevents close contact of the metal, not to mention the natural irregularity in the threads acting in the same manner. For instance, if an attempt be made to make a joint on say 8 in. pipe with a thread 6 inches long, the friction and irregularities would be so great that it would be practically impossible to get the requisite thread contact.

FIGS. 5,286 to 5,300.—Crane American Standard springler cast iron fittings for fire protection service with water working pressures up to 150 lbs. These fittings fill the requirements of the National Fire Protective Association and are made in sizes 2½ to 6 in. inclusive in the various types of elbows, tees and crane shown. Crane Standard cast iron screwed fittings size 2 in. and smaller, and standard flanged fittings will not have any opening less than 50% of the largest opening. Tappings are provided only for drain or test purposes, in which case fittings are provided with boxes for tapping when required if the location and size of tapping be specified. Fittings 2½ to 6 in. inclusive may be tapped ½ in. on the side without loss and fittings larger than 6 in. may be tapped ¾ in. without loss. All flanges and drilled templates are the American Standard.

Ques. Does the absence of heat in making up insure a tight joint?

Ans. No.

It should be understood that the absence of heat in making up does not mean the absence of grit or gum in the threads. Dirty threads may be screwed up very slowly and thus avoid the heating due to friction, and yet the joint will be anything but tight. To guard against this, after cutting the threads, *they should be* **thoroughly** *cleaned with a stiff brush.*

Ques. Are perfect threads necessary to make tight joints?

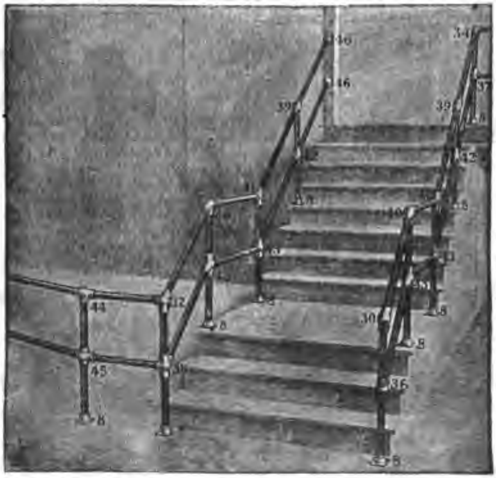


Fig. 5,301.—Kelly and Jones malleable iron railing fittings, having combination angle, screw and slip joint, vertical opening threaded. Angle openings are reamed and drilled for rivets. These fittings are for use on railings between 27½° and 47½° angles. For setting up, the parts are first screwed together and the rails are then fitted and riveted.

Ans. No.

It is surprising what erroneous ideas are held regarding the placing of too much importance on defects in threads of pipe and fittings, even by experienced pipe fitters. One of the causes assigned for the rejection of pipe and material is that the threads are a trifle broken. Probably not over 1 per cent of the bearing of the thread is gone or marred, yet there are many pipe fitters who will throw out such material. Experiments made by the Crane Co., as in figs. 5,303 and 5,304, show how absurd it is to discard such material

Ques. In taking measurements for pipe lengths what allowance must be made?

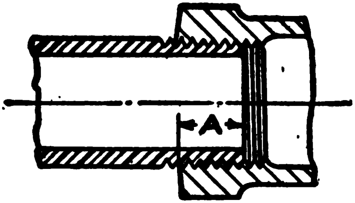
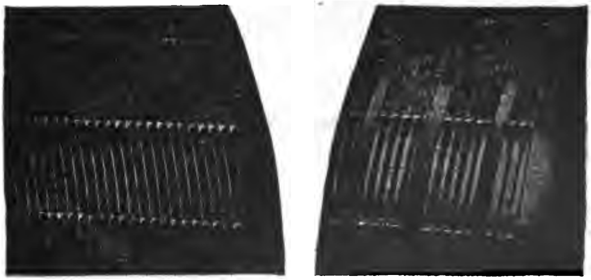
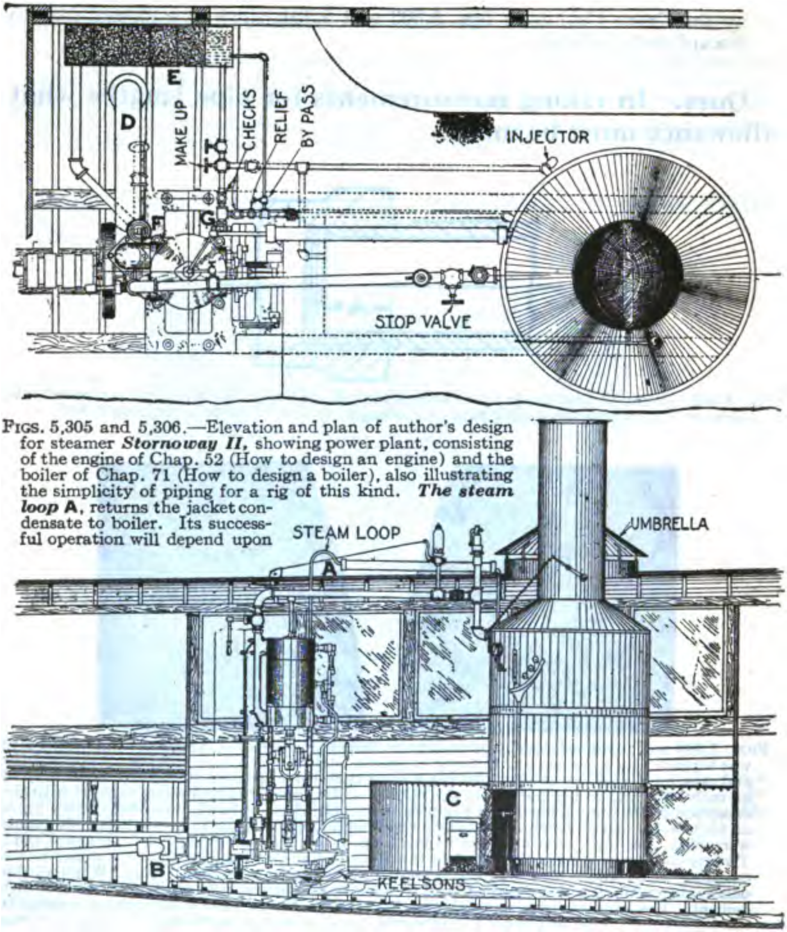


FIG. 5,302.—Screwed joint made up showing length A, of thread on pipe that is screwed into valves or fittings to make a tight joint, according to table by Crane Co. on page 2,903.



FIGS. 5,303 and 5,304.—Crane experiments on defects in threads. A piece of eight-inch pipe was threaded for a distance of two and a quarter inches. This pipe was then put in a lathe and was mutilated, as shown. In the thread part three grooves were turned, each 3/16 of an inch wide and to the bottom of the thread. The top of the remaining threads with the exception of the one at the end of the pipe, were turned off, giving them a flat surface 1/32 of an inch wide. Next, at three places on the circumference of the tapered thread, flat spots were filed, one inch wide and two inches long, extending one inch on the threaded part. Twenty-five grooves were then filed in the thread of the pipe and the same number in the coupling, all parallel with the pipe and two-thirds of the depth of the thread. When all this deliberate mutilating was finished, the threads were cleaned thoroughly and coated with cement. The joint was then screwed up so that the lengthwise grooves did not come opposite one another. The outer ends of the pipe and coupling next were plugged and the joint was tested to 425 pounds of air pressure. The joint was found to be tight, and the same result followed a hydraulic pressure test of 1,000 pounds. The amount of defect in the thread of this joint was at least one hundred times greater than that for which many regular steam fitters and engineers reject material. These tests show the amount of ignorance there has been in these matters all these years. Crane Co. reasoned this subject out, and, confident the public held a wrong theory, caused this experiment to be made. Undoubtedly the amount of material rejected for minor and wholly unimportant defects in the past, must have cost the trade many thousands of dollars.



FIGS. 5,305 and 5,306.—Elevation and plan of author's design for steamer *Stornoway II*, showing power plant, consisting of the engine of Chap. 52 (How to design an engine) and the boiler of Chap. 71 (How to design a boiler), also illustrating the simplicity of piping for a rig of this kind. ***The steam loop* A**, returns the jacket condensate to boiler. Its successful operation will depend upon sufficient length of ***drop leg*** to balance the difference of pressure between boiler and ***riser***. **B**, universal joint; **C**, coal bunker; **D**, exhaust pipe; **E**, hot well; **F**, air pump; **G**, feed pump. ***With keel condenser***, the tubes and return pipe ***must*** be inclined so ***condensate will drain from condenser inlet to air pump, otherwise little or no vacuum.*** (See author's method page 3,131). Relief valve should be placed on feed line. ***In piping***, a ***liberal number of unions*** should be used and special fittings avoided. There should be valves next to boiler on feed and main steam lines. The injector should receive its steam from separate connection to boiler instead of from main steam pipe.

Ans. An allowance for the length of thread that is screwed into valves or fittings to make a tight joint as shown in fig. 5,302.

The following table gives such allowance for various sizes of pipe

Length of Thread on Pipe

(Necessary to make a tight joint. Dimension A, fig. 5,302.)

Size inches	Dimension A inches	Size inches	Dimension A inches	Size inches	Dimension A inches	Size inches	Dimension A inches
1/8	1/4	1	9/16	3	1	6	1 1/4
1/4	3/8	1 1/4	5/8	3 1/2	1 1/16	7	1 1/4
3/8	3/8	1 1/2	5/8	4	1 1/16	8	1 5/16
......	......	......	......	......	......	9	1 3/8
1/2	1/2	2	11/16	4 1/2	1 1/8	10	1 1/2
3/4	1/2	2 1/2	15/16	5	1 3/16	12	1 5/8

Example of Pipe Fitting.—The piping system of the author's launch, "Stornoway," as shown in fig. 5,305, is an illustration of an installation comprising numerous lengths of pipe and a multiplicity of fitting, and most of it being located below the floor timbers of a small boat presents some difficulty which taxes the ingenuity of the fitter. The boat being operated in salt water, brass pipe and fittings are used to prevent rapid corrosion, except the exhaust pipe, which is of copper with flanged joints.

There are two methods by which the pipe fitting may be done:

1. By eye and approximate measurements, or
2. Entirely by measurements.

The first method is a hit or miss process and requires an experienced fitter to make a good job, whereas, the second method is one of precision and is the better way of doing it because in making up the various lines it is not necessary to bring undue strain on them by springing them into position to correct small errors in cutting to wrong lengths.

In actual practice a combination of the two methods will save time and give satisfactory results. Thus, where there is a little margin for adjustment in making up a line, as for instance, the pump lines to hot well with their lock nut joints, such lines can be proportioned "by eye."

The pipe fitting for the installation shown in fig. 5,318, should be done about as follows:

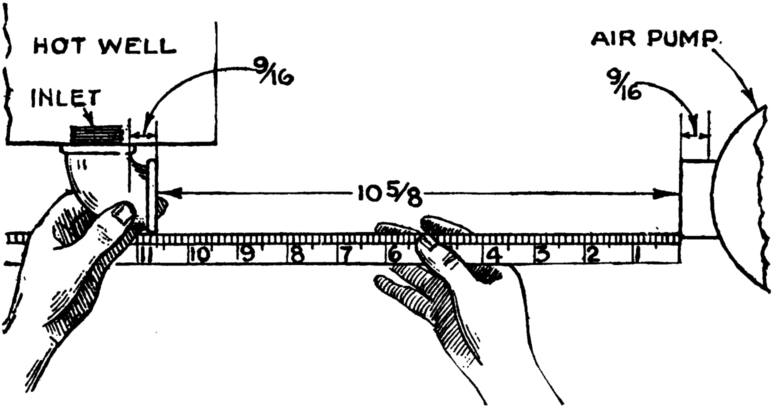


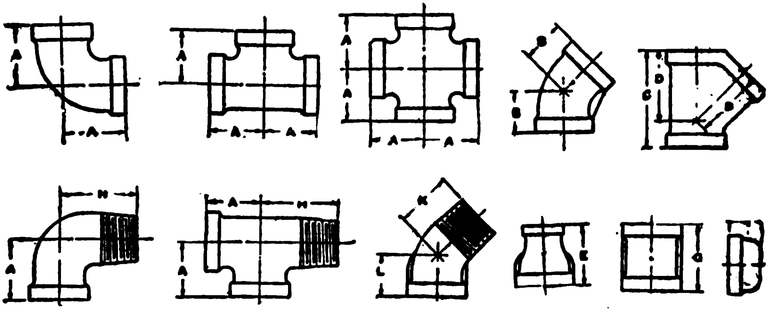
FIG. 5,306.—Detail of air pump connection to hot well showing method of measuring pipe length.

Place the hot well in position close to the side of the boat Now make up the short line between the feed pump and hot well, proportioning the two short nipples (by eye) so that the lock nut joint will come in the right position Screw up lock nuts temporarily by hand. This locates the position of the hot well. In making up, be careful that the tee outlet points horizontally and that the check valve cap is on top. The air pump connection should be made next.

To get the length of the pipe, hold the elbow up against the inlet hole in end of hot well and measure from the face of air pump connection, to the face of elbow as shown in fig. 5,306. Now the size of the pipe being one inch, a margin of 9/16 in. must be allowed, according to table on page 2,903 in order to make a tight joint. Hence, total length of pipe connecting pump and elbow is

$$10\frac{5}{8}+2\times\frac{9}{16}=11\frac{3}{4}$$

Cut pipe to 13¾ ins. in length and thread each end. Screw elbow on one end before taking pipe out of vise. The pipe is screwed into air pump outlet and on the last turn bring elbow fair with hole in hot well. Unscrew lock nut on feed pump connection and remove hot well. Screw into elbow a close nipple with long thread at the other end, with one lock nut screwed on. Now replace hot well and make up permanently the two lock nut joints, using gaskets or packing and red lead to make tight joints.



FIGS. 5,307 to 5,317.—General dimensions of Crane standard malleable iron screwed fittings. The reference letters refer to the table below.

General Dimensions Crane Standard Malleable Iron Secrewed Fittings.

Size Inches	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	6	7	8
A. . Inches	11/16	11/16	13/16	1 1/8	1 3/16	1 7/16	1 3/4	1 15/16	2 1/4	2 11/16	3 1/8	3 7/16	3 3/4	4 1/16	4 7/16	5 1/8	5 11/16	6 1/2
B. . Inches		3/4	13/16	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16	1 15/16	2 3/16	2 3/8	2 5/8	2 13/16	3 1/16	3 7/16	3 7/8	4 1/4
C. . Inches				2 1/2	2 7/8	3 7/16	4 1/16	4 1/2	5 7/16	6 1/4	7 1/4		8 7/8					
D. . Inches				1 11/16	2	2 7/16	2 13/16	3 5/16	4 1/16	4 11/16	5 9/16		6 15/16					
E. . Inches		1	1 1/8	1 1/4	1 7/16	1 11/16	2 1/16	2 5/16	2 13/16	3 1/4	3 11/16	4	4 3/8					
F. . Inches		5/8.	3/4	7/8	1 1/16	1 3/16	1 1/4	1 5/16	1 7/16	1 5/8	1 3/4	1 13/16	2		2 5/16	2 9/16		
G. . Inches		1 1/16	1 3/16	1 5/16	1 1/2	1 11/16	1 13/16	2 1/8	2 1/2	2 7/8	3 3/16							
H. . Inches	1 1/8	1 3/16	1 7/16	1 5/8	1 7/8	2 1/8	2 1/2	2 11/16	3 3/16	3 13/16	4 1/2		5 11/16					
K. . Inches		13/16	1 1/16	1 3/16	1 5/16	1 1/2	1 11/16	1 7/8	2 1/4		3		3 3/4					
L. . Inches		11/16	11/16	13/16	15/16	1 1/16	1 1/4	1 3/8	1 11/16		2 1/8		2 1/2					

In order to avoid frequent change of dies in the stock, it is well to make up lines of one size when it can be conveniently done, before taking up another size; this avoids variations due to readjustment of dies when adjustable dies are used. Accordingly the feed, make up, and overflow lines being of the same size, these should be made up before changing the dies.

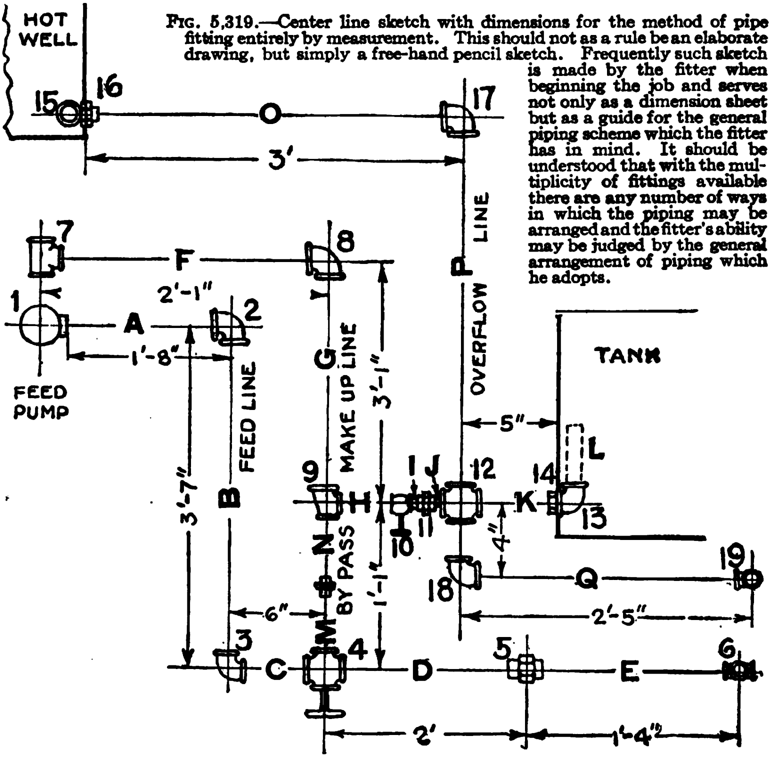
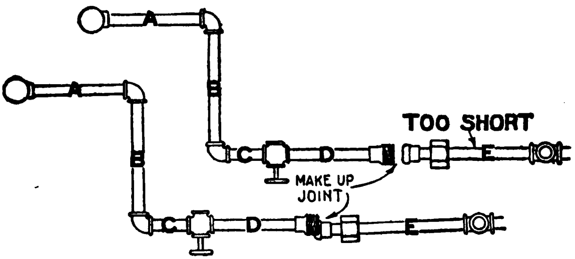


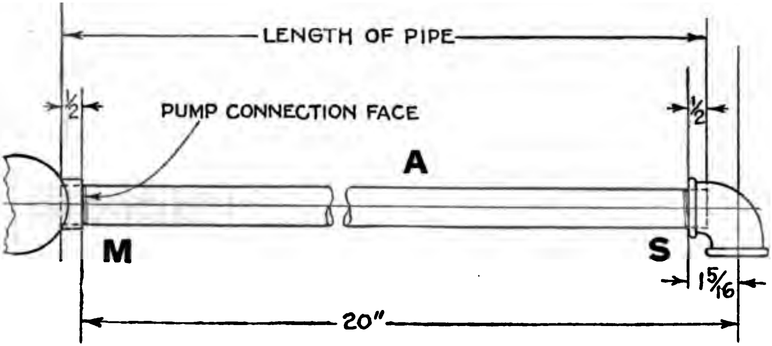
Fig. 5,319.—Center line sketch with dimensions for the method of pipe fitting entirely by measurement. This should not as a rule be an elaborate drawing, but simply a free-hand pencil sketch. Frequently such sketch is made by the fitter when beginning the job and serves not only as a dimension sheet but as a guide for the general piping scheme which the fitter has in mind. It should be understood that with the multiplicity of fittings available there are any number of ways in which the piping may be arranged and the fitter's ability may be judged by the general arrangement of piping which he adopts.



Figs. 5,320 and 5,321.—Detail of feed line ready to "make up". Fig. 5,320 shows ***poor workmanship,*** nipple **E**, being too short rendering it difficult to bring together the make up joint. Fig. 5,321 shows ***good workmanship;*** here the male end of the union will easily spring back into position in making up the joint..

Make a center line sketch of these lines with dimensions as in fig. 5,318. Pipe up first the feed line. This line as shown consists of pipes A,B,C, D,E, pump connection 1, and fittings 2,3,4,5 and 6. Now determine overall dimensions of A,B,C,D,E, thus:

Pipe	Distance between centers	Fitting number	Center to face of fitting inches (subtract)	Allow for threads inches (add)	Overall length pipe
A	1′ 8″	2	1 5/16	1/2	19 11/16
B	3′ 7″	3	1 5/16	1/2	44 5/8
C	6″	4	*1 5/8	1/2	4 1/16
D	2′	5	*1 1/16	1/2	22 1/4
E	1′ 4″	6	1 5/16	1/2	14 5/8



FIGS. 5,319.—Detail of a portion of the feed line showing method of determining length of pipe A.

Figs. 5,307 to 5,317 show standard malleable iron screwed fittings, the reference letters indicating the general dimensions in the accompanying table:

To determine overall dimensions of pipe A, note in fig. 5,318 the distance between pump connection face and center of elbow 2, is 1 foot 8 inches, or 20 inches, as shown in detail in fig. 5,319. From table above, the distance from center of fitting 2, to face is 1 5/16 inches and from table (page 2,903), length of thread which must be screwed into fitting to make a light joint is (for 3/4 inch pipe) 1/2 inch. Accordingly, from fig. 5,319 the length of pipe A is clearly:

---

* **NOTE.—From Lunkenheimer's catalogue.**

There is no hard and fast rule of procedure. The experienced fitter will do a considerable proportion of the piping "by eye," only taking measurements where necessary.

The exhaust pipe is of copper bent to template, with flanged connection at each end. The condenser tubes are made tight by stuffing boxes in the headers. The return to air pump is standard weight pipe with screw joints.

Fig. 5,306 shows the main steam pipe with an elbow connecting the horizontal with the vertical length; a better job would consist of bending the pipe in place of elbows. This should preferably be done with proper facilities at the shop, unless the fitter be experienced in bending and has proper facilities at hand.

Properties of Standard Wrought Pipe

Size	Diameters		Nominal Thickness	Circumference		Transverse Areas			Length of Pipe per Square Foot of		Length of Pipe Containing One Cubic Foot	Nominal Weight per Foot		Number of Threads Per Inch of Screw
	External	Approximate Internal		External	Internal	External	Internal	Metal	External Surface	Internal Surface		Plain Ends	Threaded and Coupled	
Inches	Inches	Inches	Inches	Inches	Inches	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Feet			
⅛	.405	.269	.068	1.272	.845	.129	.057	.072	9.431	14.199	2533.775	.244	.245	27
¼	.540	.364	.088	1.696	1.144	.229	.104	.125	7.073	10.493	1383.789	.424	.425	18
⅜	.675	.493	.091	2.121	1.549	.358	.191	.167	5.658	7.747	754.360	.567	.568	18
½	.840	.622	.109	2.639	1.954	.554	.304	250	4.547	6.141	473.906	.850	.852	14
¾	1.050	.824	113	3.299	2.589	.866	.533	.333	3.637	4.635	270.034	1.130	1.134	14
1	1.315	1.049	.133	4.131	3.296	1.358	.864	.494	2.904	3.641	166.618	1.678	1.684	11½
1¼	1.660	1.380	.140	5.215	4.335	2.164	1.495	.669	2.301	2.767	96.275	2.272	2.281	11½
1½	1.900	1.610	.145	5.969	5.058	2.835	2.036	.799	2.010	2.372	70.733	2.717	2.731	11½
2	2.375	2.067	.154	7.461	6.494	4.430	3.355	1.075	1.608	1.847	42.913	3.652	3.678	11½
2½	2.875	2.469	203	9.032	7.757	6.492	4.788	1.704	1.328	1.547	30.077	5.793	5.819	8
3	3.500	3.068	216	10.996	9.638	9.621	7.393	2.228	1.091	1.245	19.479	7.575	7.616	8
3½	4.000	3.548	.226	12.566	11.146	12.566	9.886	2.680	.954	1.076	14.565	9.109	9.202	8
4	4.500	4.026	.237	14.137	12.648	15.904	12.730	3.174	.848	.948	11.312	10.790	10.889	8
4½	5.000	4.506	.247	15.708	14.156	19.635	15.947	3.688	.763	.847	9.030	12.538	12.642	8
5	5.563	5.047	.258	17.477	15.856	24.306	20.006	4.300	.686	.756	7.198	14.617	14.810	8
6	6.625	6.065	.280	20.813	19.054	34.472	28.891	5.581	.576	.629	4.984	18.974	19.185	8
7	7.625	7.023	301	23.955	22.063	45.664	38.738	6.926	.500	.543	3.717	23.544	23.769	8
8	8.625	8.071	277	27.096	25.356	58.426	51.161	7.265	.442	.473	2.815	24.696	25.000	8
8	8.625	7.981	.822	27.096	25.073	58.426	50.027	8.399	.443	.478	2.878	28.554	28.809	8
9	9.625	8.941	.342	30.238	28.089	72.760	62.786	9.974	396	.427	2.294	33.907	34.188	8
10	10.750	10.192	279	33.772	32.019	90.763	81.585	9.178	.355	.374	1.765	31.201	32.000	8
10	10.750	10.136	.307	33.772	31.843	90.763	80.691	10.072	355	.376	1.785	34.240	35.000	8
10	10.750	10.020	.365	33.772	31.479	90.763	78.855	11.908	355	.381	1.826	40.483	41.132	8
11	11.750	11.000	.375	36.914	34.558	106.431	95.033	13.401	325	.347	1.515	45.557	46.247	8
12	12.750	12.090	.330	40.055	37.982	127.676	114.800	12.876	.299	.315	1.254	43.773	45.000	8
12	12.750	12.000	.375	40.055	37.699	127.676	113.097	14.579	299	.318	1.273	49.562	50.706	8

NOTE.—***Pipe practice*** or *customs of the trade:* On orders calling for commercial sizes of pipe to be furnished with threads and couplings in sizes ⅛ to 12 inch, inclusive, where orders specify quantity in lineal feet it is understood that random lengths, threaded both ends, with coupling on one end, will be shipped, and the measurement is charged from end to end, that is, over all including coupling. Orders or inquiries covering cut lengths of any size should specify whether plain ends, threads only, threads and couplings, or flanges are required. A separate charge is made for couplings or flanges, either loose or screwed on pipe, when pipe is ordered cut to specified lengths.—*Continued on page* 2,910.

$$\left.\begin{array}{c}\text{Pump connection face}\\ \text{to}\\ \text{center of fitting 2}\end{array}\right\} + \text{thread at M} - \left\{\begin{array}{c}\text{center to face}\\ \text{of fitting}\end{array}\right\} + \text{thread at S} = \text{length of pipe}$$

$$20 \quad + \quad \tfrac{1}{2} \quad - \quad 1\tfrac{5}{16} \quad + \quad \tfrac{1}{2} \quad = \quad 19\tfrac{11}{16}$$

Similarly for pipe B:

$$\left.\begin{array}{c}\text{Distance between}\\ \text{center fittings}\\ \text{2 and 3}\end{array}\right\} + \left\{\begin{array}{c}2 \times \text{center to face}\\ \text{of fitting}\end{array}\right\} - 2 \times \text{thread} = \text{length of pipe}$$

$$43 \quad + \quad 2\times 1\tfrac{5}{16} \quad - \quad 2\times\tfrac{1}{2} \quad = \quad 44\tfrac{5}{8}$$

In like manner the lengths of pipes C, D, E, are obtained.

Cut and thread all these pipes except pipe E. Start at the feed pump and make up the line up to D, including end *x*, of union 5.

Now with the union screwed together temporarily, measure the distance between faces of the union 5 and tee 6. The sum of this distance plus the distances from center to face of fittings will probably vary a little from the dimension 1 foot 4 inches, due to inaccuracies in make up and cutting. Hence, to avoid strain on the line (assuming tee 6, fig. 5,318) to be fixed, make length of pipe E, equal to measured distance between faces of fittings plus 1 inch margin for both threads.

After cutting threads on both ends of pipe E, screw on the *y* end of union 5, while the pipe is in the vise. If *y* be the ring end of the union, be sure the ring is on before screwing the pipe into tee 6. To make up the union spring both ends into place and screw on the ring firmly, thus completing the feed line.

In a similar manner next pipe up the make up line. Start at tee 7 and make up the line to reducing tee 9. If the measurements and work are accurate, this tee should be in alignment with by pass valve 4; if much out, the length of pipe F, must be changed. Get two short nipples I and J, and make up the section consisting of these nipples, valves 10 and 12, and union 11. Cut and thread pipe K, and make up the line from valve 10 to pipe L. See that the valves point right and pipe L, to the bottom of the tank.

Next pipe up the overflow line from valve 12 to overflow pipe 15 in hot well. The locknut 14 should now be firmly screwed up against packing to make a water tight joint. Pipe H, can now be measured, cut and threaded. Before removing it from the vise unscrew ring of union 11 and screw on valve 10. Remove from vise and screw the other end of pipe H, into tee 9. Spring into place and make up union 11, thus completing the line.

After all the ¾-inch piping has been installed, change dies to ½-inch size.

First find by measure length of pipe M, and N. Cut, thread and make up the by pass line. If the work has been accurate, there should be no trouble in making up union 20. The rest of the screwed piping is put together in a similar manner.

Properties of Extra Strong* Pipe

DIAMETER			Nominal Thickness	CIRCUMFERENCE		TRANSVERSE AREAS			LENGTH OF PIPE PER SQUARE FOOT OF		Length of Pipe Containing One Cubic Foot	Nominal Weight per Foot Plain Ends
Nominal Internal Inches	External Inches	Approximate Internal Diameter Inches	Inches	External Inches	Internal Inches	External Sq. Inches	Internal Sq. Inches	Metal Sq. Inches	External Surface Feet	Internal Surface Feet	Feet	Pounds
⅛	.405	.215	.095	1.272	.675	.129	.036	.093	9.431	17.766	3966.392	.314
¼	.540	.302	.119	1.696	.949	.229	.072	.157	7.073	12.648	2010.290	.535
⅜	.675	.423	.126	2.121	1.329	.358	.141	.217	5.658	9.030	1024.689	.738
½	.840	.546	.147	2.639	1.715	.554	.234	.320	4.547	6.995	615.017	1.087
¾	1.050	.742	.154	3.299	2.331	.866	.433	.433	3.637	5.147	333.016	1.473
1	1.315	.957	.179	4.131	3.007	1.358	.719	.639	2.904	3.991	200.193	2.171
1¼	1.660	1.278	.191	5.215	4.015	2.164	1.283	.881	2.301	2.988	112.256	2.996
1½	1.900	1.500	.200	5.969	4.712	2.835	1.767	1.068	2.010	2.546	81.487	3.631
2	2.375	1.939	.218	7.461	6.092	4.430	2.953	1.477	1.608	1.969	48.766	5.022
2½	2.875	2.323	.276	9.032	7.298	6.492	4.238	2.254	1.328	1.644	33.976	7.661
3	3.500	2.900	.300	10.996	9.111	9.621	6.605	3.016	1.091	1.317	21.801	10.252
3½	4.000	3.364	.318	12.566	10.568	12.566	8.888	3.678	.954	1.135	16.202	12.505
4	4.500	3.826	.337	14.137	12.020	15.904	11.497	4.407	.848	.998	12.525	14.983
4½	5.000	4.290	.355	15.708	13.477	19.635	14.455	5.180	.763	.890	9.[illegible]62	17.611
5	5.563	4.813	.375	17.477	15.120	24.306	18.194	6.112	.686	.793	7.915	20.778
6	6.625	5.761	.432	20.813	18.099	34.472	26.067	8.405	.576	.663	5.524	28.573
7	7.625	6.625	.500	23.955	20.813	45.664	34.472	11.192	.500	.576	4.177	38.048
8	8.625	7.625	.500	27.096	23.955	58.426	45.663	12.763	.442	.500	3.154	43.388
9	9.625	8.625	.500	30.238	27.096	72.760	58.426	14.334	.396	.442	2.464	48.728
10	10.750	9.750	.500	33.772	30.631	90.763	74.662	16.101	.355	.391	1.929	54.735
11	11.760	10.750	.500	36.914	33.772	108.484	90.763	17.671	.325	.355	1.587	60.075
12	12.750	11.750	.500	40.055	36.914	127.676	108.434	19.242	.299	.325	1.328	65.415

Properties of Double Extra Strong* Pipe

DIAMETER			Nominal Thickness	CIRCUMFERENCE		TRANSVERSE AREAS			LENGTH OF PIPE PER SQUARE FOOT OF		Length of Pipe Containing One Cubic Foot	Nominal Weight per Foot Plain Ends
Nominal Internal Inches	External Inches	Approximate Internal Diameter Inches	Inches	External Inches	Internal Inches	External Sq. Inches	Internal Sq. Inches	Metal Sq. Inches	External Surface Feet	Internal Surface Feet	Feet	Pounds
½	.840	.252	.294	2.639	.792	.554	.050	.504	4.547	15.157	2887.164	1.714
¾	1.050	.434	.308	3.299	1.363	.866	.148	.718	3.637	8.801	973.404	2.440
1	1.315	.599	.358	4.131	1.882	1.358	.282	1.076	2.904	6.376	510.998	3.659
1¼	1.660	.896	.382	5.215	2.815	2.164	.630	1.534	2.301	4.263	228.379	5.214
1½	1.900	1.100	.400	5.969	3.456	2.835	.950	1.885	2.010	3.472	151.526	6.408
2	2.375	1.503	.436	7.461	4.722	4.430	1.774	2.656	1.608	2.541	81.162	9.029
2½	2.875	1.771	.552	9.032	5.564	6.492	2.464	4.028	1.328	2.156	58.457	13.695
3	3.500	2.300	.600	10.996	7.226	9.621	4.155	5.466	1.091	1.660	34.659	18.583
3½	4.000	2.728	.636	12.566	8.570	12.566	5.845	6.721	.954	1.400	24.637	22.850
4	4.500	3.152	.674	14.137	9.902	15.904	7.803	8.101	.848	1.211	18.454	27.541
4½	5.000	3.580	.710	15.708	11.247	19.635	10.066	9.569	.763	1.066	14.306	32.530
5	5.563	4.063	.750	17.477	12.764	24.306	12.966	11.340	.686	.940	11.107	38.552
6	6.625	4.897	.864	20.813	15.384	34.472	18.835	15.637	.576	.786	7.646	53.160
7	7.625	5.875	.875	23.955	18.457	45.664	27.109	18.555	.500	.650	5.312	63.079
8	8.625	6.875	.875	27.096	21.598	58.426	37.122	21.304	.442	.555	3.879	72.424

NOTE.—Sizes 3½ inch and larger are made by telescoping.

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*NOTE.—The word ***heavy*** was formerly used in place of ***strong***.

NOTE.—***Pipe practice*** or *customs of the trade:* Orders for pipe larger than 12 in. should specify the actual outside diameter of the pipe and the thickness of the wall. Standard weight pipe is listed and carried in stock threaded and coupled and will be shipped unless order specified otherwise. Extra strong, double extra strong, hydraulic, and large *o.d.* pipe is listed plain ends only and will be so shipped unless order specifies otherwise. An extra charge is made for threads and couplings on these weights. For pipe smoothed on the inside, known as reamed and drifted, an extra charge is made. Such pipe is furnished in random lengths 20 feet and shorter. Random lengths of extra strong and double extra strong pipe are considered to be 12 to 22 feet, dealer to have privilege of supplying not to exceed 5 per cent of total order in lengths 6 to 12 feet. For cut lengths of any size an extra charge above random lengths will be made. For galvanized or asphalted pipe an extra charge above black will be made. Sizes 8, 10 and 12 inch standard pipe are listed in several weights and orders or inquiries should specify the weight required.

CHAPTER 83

HEATING AND VENTILATION

A great variety of methods have been tried for heating buildings. Many of these are more or less objectionable, and yet they are still in use. These various methods may be classified

1. With respect to the *medium* which conveys the heat, as

a. Air.
b. Water.
c. Steam.
d. Electricity.

2. With respect to the location of the *source* of heat, as

a. In the room to be warmed	***fire places*** ***stoves***
b. Outside of room to be warmed	***furnaces*** ***boilers*** ***dynamos***

3. With respect to their efficiency and desirability, as

a. Fire places (oldest and poorest method).
b. Stoves.
c. Hot air furnaces.
d. Steam.
e. Hot water.
f. Electricity (under very special conditions).

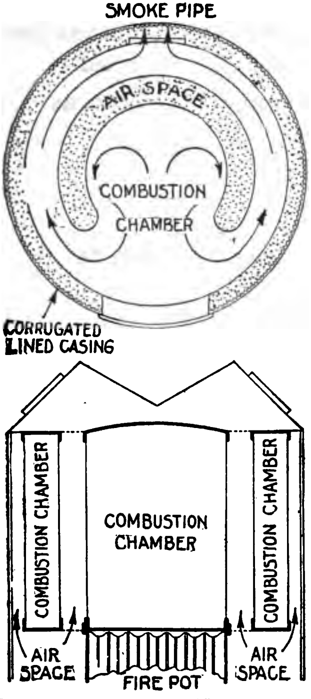
Of the various systems, steam and hot water heating are the most important.

Fire Places.—The old fashioned open fire place is the oldest and poorest method of heating. The only advantages it possesses are its action in ventilating a room, and the cheerfulness that an open fire affords. The carrying in and out of coal and ashes renders this a dirty method of heating, and one that requires frequent attention.

It is inadequate in cold weather and should be considered only as a supplemental form of heating for spring and fall before the weather becomes cold enough to use the regular system of heating.

Stoves.—Much more efficient is a stove than a fire place for heating a room. For a large room or small house, where one stove will furnish all the heat needed, it is the cheapest and most economical system to install, especially if conditions permit a long length of the stove pipe within the room, so as to absorb a proper amount of heat from the escaping gases.

Stoves, however, have several objections. The metal of the stove is heated to a very high temperature which: robs the air of its oxygen, causing headache unless adequate ventilation be maintained; unless the dampers



Figs. 5,323 and 5,324.—Upper construction or "radiator" of Boynton square pot hot air furnace showing relation of parts; also, travel of hot air and heated gases of combustion.

Figs. 3,325 and 3,326.—Dome and double radiator of Mueller hot air furnace showing construction and path of gases.

be properly manipulated there is danger from the gases, especially in sleeping rooms; considerable attention is required to produce an even temperature; the handling of the coal and ashes requires considerable cleaning and dusting.

Hot Air Furnaces.—These are not much more satisfactory than stoves, and nearly all of them are too small. They are only used by people who do not think further than first cost, and who are afraid of being blown up by the mere mention of the word "steam." A hot air furnace is, in effect, a stove in the basement with large air flues to conduct the heated air to the various rooms of the house. This method of heating is condemned by physicians as unsanitary, because the heating surface, being maintained at a very high temperature, devitalizes the air, and due to constant expansion and contraction of the metal, the joints begin to leak, thus letting dust and gases escape into the living rooms.

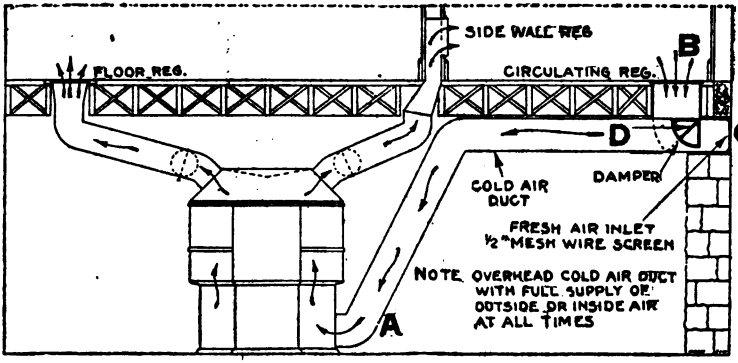


FIG. 5,327.—Method of hot air heating with outside and inside air circulation. The air to be heated enters the furnace through a duct at A. This air duct connects with a circulating register B, and is open to the outside atmosphere at C, either of which may be closed by a damper at B and C. When B, is closed all the air to be heated comes in from the outside through C, thus heating and ventilating at the same time. When C is closed (B open), no air is taken in from the outside, the inside air circulating between the furnace and rooms to be heated. A combination of the two methods may be obtained by placing the dampers at intermediate positions. Any hot air furnace system is objectionable and has nothing to recommend it except first cost, and this is a poor recommendation.

There are two methods of heating by hot air furnaces:

1. Where all the air for both heating and ventilation is taken from out doors and exhausted from the building.

2. Where only the air for ventilation is taken from outdoors, and additional air is recirculated through the furnace from the building itself.

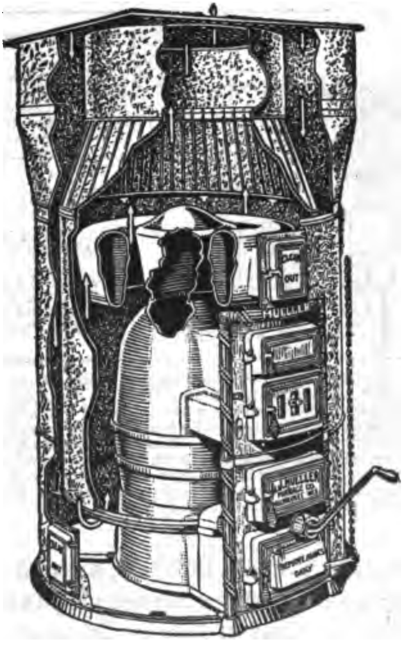


FIG. 5,328.—Mueller ***pipeless*** furnace. ***In construction,*** the furnace is surrounded by an outer casing and an inner casing, the latter terminating about one foot from the bottom, so that air will circulate under it. Instead of having pipes running out at various angles to carry the heat into different parts of the house, the inner and outer casings are both carried up to the floor and fastened to a large floor register. ***In operation*** the warm air from the furnace passes in a steady current up through the inner circle of the register and circulates throughout the entire house. The cold air, being heavier, descends to the floor and finds a natural outlet or escape through the outer compartment of the register into the space between the inner and outer jacket of the furnace, thence passes into the space next the furnace proper where it is reheated and again sent up to fulfill its heating function.

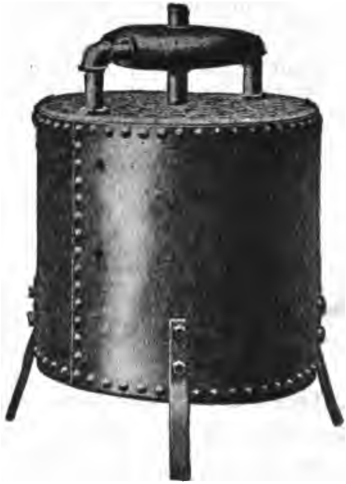


FIG. 5,329.—Pease boiler of ***combination*** steam and air heater.

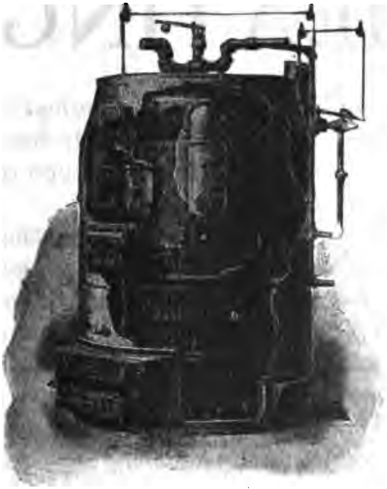


FIG. 5,330.—Pease ***combination*** steam and air heater. ***Advantages*** (as stated by the manufacturer): "Compared with direct steam or hot water heating, or with warm air furnaces alone, the manifest advantages of a combined system are apparent to anyone familiar with heating problems. In rooms that can be most easily reached by warm air pipes, and these are usually the ones most used, fewer radiators and smaller ones are required than with direct steam or hot water, and wall space valuable for furniture is retained. On the other hand, distant rooms, exposed bay windows and angles are easily protected with the direct radiators, where it would be impossible to warm them with a furnace only. In mild weather, on chilly nights and mornings of late spring or early fall, a little fire will diffuse a pleasant supply of fresh warmed air through the entire building, when under similar conditions a direct steam plant would render the building intolerable; since no heat would be obtainable until the water was raised to the boiling point (212°) and then the supply would be excessive. The radiators being placed in the most exposed portions of the building heated with a combined apparatus, in severe cold or windy weather an even temperature is maintained throughout all the apartments, while the fresh, invigorating warmed air from the registers gives a zest and tone to the indoor atmosphere like that of a June morning."

The first method which is the one generally used, is an exceedingly wasteful one, especially in cold weather. Although it is claimed to be possible to heat a building by the second method as economically as with steam or hot water, the escaping gases through leaks in the furnace would preclude the use of this method where there is any regard for health.

1

STEAM HEATING

This is a very effective, and sometimes too effective method of heating. In its various forms it is probably more widely used than any other system, being adapted to almost any type of building.

Some advantages of steam heating are the ability of heating all rooms uniformly, regardless of their location or the direction of the wind, a condition which seriously affects heating with hot air furnaces; steam is quickly raised in the morning and when a radiator is shut off the small amount of condensation remaining is not sufficient to cause freezing.

The disadvantages are lack of control, and devitalizing effect on the air due to the high temperature of the radiating surfaces. The first objection has given rise to numerous modified systems of steam heating which render steam as a heating medium as satisfactory as hot water.

The various systems of steam heating may be classified:

1. With respect to the working pressure, as

   a. Low pressure (1 to 10 pounds).
   b. Atmospheric pressure (so called "vapor").
   c. Vacuum.
   d. Combined vacuum-vapor.

2. With respect to the method of piping, as

- *a. One Pipe*
  - relief
  - circuit system
  - divided circuit system
  - circuit system with loop
  - dry returns
  - wet returns
  - underconnected
  - overhead
- *b. Two Pipe*
  - under feed
  - over feed

3. With respect to the method of transmitting the heat, as

a. Direct.
b. Indirect.

LOW PRESSURE STEAM SYSTEMS

There are two principal low-pressure steam systems, the **one pipe** and the **two pipe,** the circuit being modified in various ways to suit conditions.

When it is necessary to install steam heat in a long, narrow building, where the radiators are all placed along the outside wall, the one pipe system is especially suited.

For ordinary work it is preferred to the two pipe system, although the latter is in favor with some fitters. The cost of installation is less with the one pipe system, even with the smaller size piping used with the two-pipe system.

It is customary when using the two pipe system to reduce the size of the main as the various radiators are taken off. Caution should be exercised not to overdo this, in order to guard against inefficient operation of the remote radiators, making it necessary to carry excess pressure on the boiler to insure proper operation of all the radiators.

One Pipe Underfeed Relief System.—There are various piping arrangements of the one pipe system. Fig. 5,331 shows what is called the one pipe relief system.

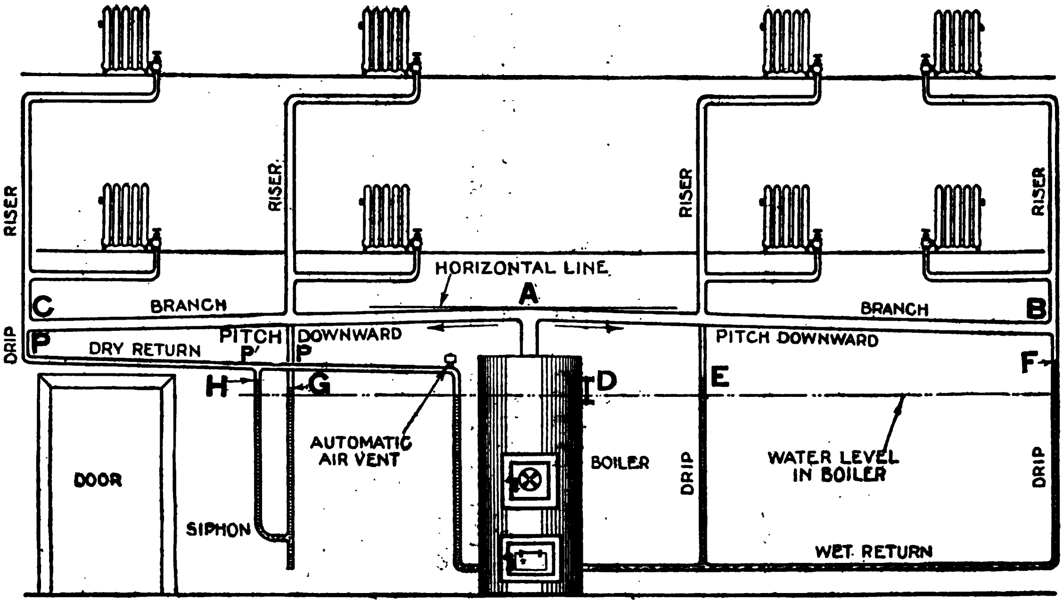


FIG. 5,331.—One pipe relief steam heating system showing 1, *dry* returns to the right, and 2, *wet* returns to the left. The wet return is the natural method of piping but frequently it is desirable to have the return elevated to near the ceiling where passing across doors, etc. This arrangement is called a dry return because it does not *fill* with condensation as when placed below the water level.

Connected to the main outlet A, are two or more branch mains, AB, and AC, which supply the various risers.

Steam is supplied to each radiator and the condensation removed by a single pipe or riser, hence the name, "one pipe system."

The condensation returns to the boiler by gravity through drip pipes, which are virtually continuations of the risers below the branch mains, and which connect with the return pipe so that the condensation will flow back into the boiler.

Ques. What is the difference between a wet or sealed, and a dry return?

Ans. A wet return is placed *below* the water level in the boiler, whereas a dry return is *above* the water level.

Fig. 5,331 shows both wet and dry returns.

Ques. What is the advantage of a wet return?

Ans. It seals the drips from the risers and prevents steam at a slightly higher pressure entering the return.

Ques. Describe the operation of the system shown in fig. 5,331.

Ans. Steam (usually at from 1 to 5 pounds pressure), passes from the boiler to the branches, AB, and AC; these branches being slightly inclined, any water in the steam draws into the drip pipe. The steam passes through the risers to the radiators, where its heat is radiated in warming the rooms, thus causing condensation. The risers being of liberal size, the condensation is carried by gravity against the direction of flow of the steam, and deposited in the drip pipes, where it gravitates via the returns to the boiler.

A characteristic feature of such systems is that there is a slight difference in pressure in the different parts of the system due to the frictional resistance offered by the pipe to the flow of the steam, this flow varying because of more rapid condensation in some radiators than in others. Thus, if the water level in the boiler be at D, then in operation, with a wet return (fig. 5,331), the pressure difference will be balanced by the water standing at different levels in the different drip pipes, as at E, and F.

When it becomes necessary to carry the return pipes overhead to clear doorways, or for any other reason, the effect of a wet return may be obtained by attaching a *siphon* to the bottom of the drip pipe as shown at the left in fig. 5,331. The water from the drip falls into the loop formed by the siphon and after it is filled, overflows into the dry return. The water will rise to different heights G, and H, in the legs of the siphon to balance the difference in pressure at points P, and P′. Now, if the siphon were omitted and the drip pipe connected direct to the dry return, then there would be a tendency for the condensate in the dry return to back up instead of draining into the boiler because the pressure in the drip pipe at P, is greater than the pressure in the dry return. Fig. 5,332 shows in detail the effect of pressure variation.

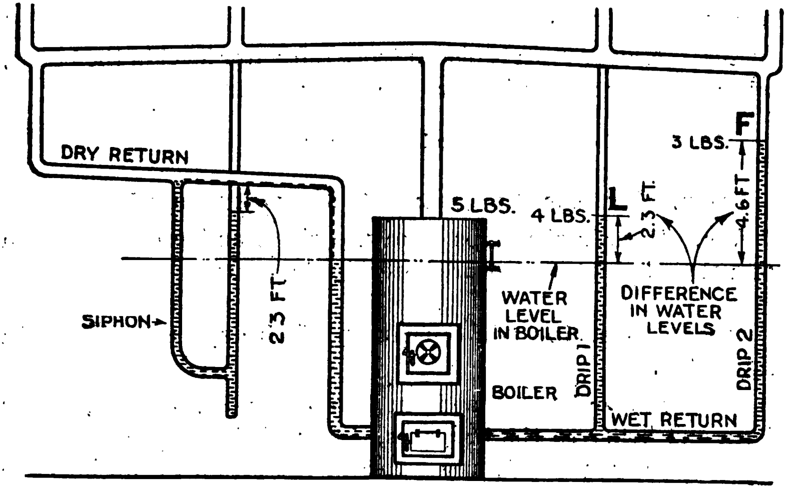
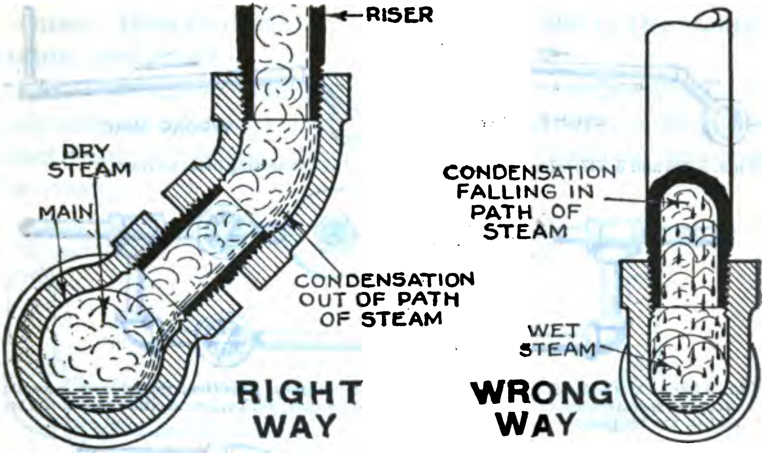


FIG. 5,332.—Detail of boiler and returns of fig. 5,331, showing effect of pressure variation in different parts of the system. *In general, there is a gradual reduction of pressure as the steam flows from the boiler to the remote parts of the system.* This is due to the frictional resistance offered by the pipe and fittings to the flow of the steam. Hence this variation in pressure *only exists when the steam is flowing in the pipes and in order for the steam to flow in the pipes there must be condensate.* Now, in the figure, when the plant is in operation with condensation taking place in the radiators and draining into the drip pipes, suppose the pressure in the boiler be 5 lbs; in drip 1, 4 lbs, and in drip 2, 3 lbs. Then, to balance these pressure differences the water will rise in drip 1 to L 2.3 ft. above the water level in the boiler because there is a pressure difference of 5—4=1 lb. and the weight of a column of water 2.3 ft. is 1 lb. for each sq. in. of cross section. Similarly, for drip 2, the pressure difference is 2 lbs., hence the water will rise twice this distance above the water level in the boiler, or 2.3×2=4.6 ft. to balance the 2 lbs. pressure difference.


RISER
DRY STEAM
MAIN
CONDENSATION OUT OF PATH OF STEAM
RIGHT WAY
CONDENSATION FALLING IN PATH OF STEAM
WET STEAM
WRONG WAY

Figs. 5,333 and 5,334.—***Right*** and ***wrong*** way of connecting risers to mains. A good many steam fitters to avoid extra labor and expense connect risers direct to the main with simply a tee as shown in fig. 5,334. It requires no deep thought to understand that some of the condensation from the radiators above falling into the main directly in the path of the steam flowing through the main will be taken up and carried by the steam into the next riser, thus arriving at the radiator with considerable more moisture than would be the case if the piping were arranged as in fig. 5,333, where the condensation would run down the side out of the path of the steam. According to one authority, the saturating and cooling effect occasioned piping the wrong way as in fig. 5,334 may reduce the efficiency as much as 5%.

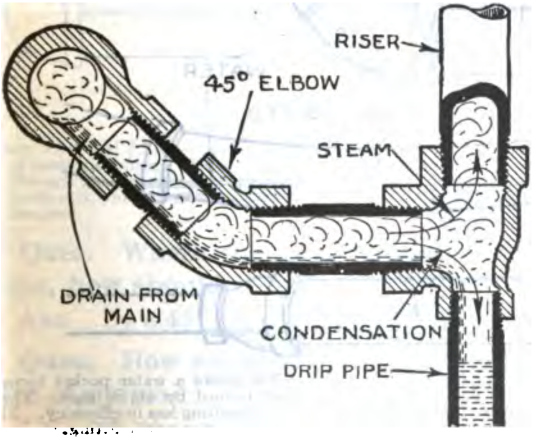
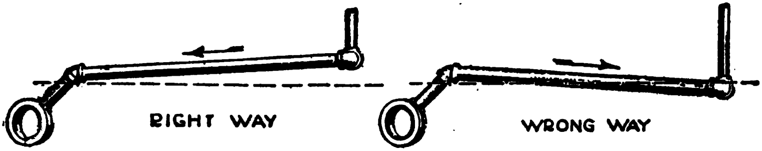


Fig. 5,335. — Proper method of connecting riser to main where riser has direct connected drip pipe. By using a 45° street elbow only one nipple is required. With this arrangement the main is very effectively drained of condensation, thus increasing the efficiency of the system.



FIGS. 5,336 and 5,337.—Right and wrong methods of connecting main to riser.

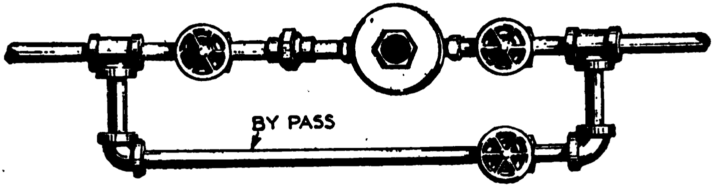
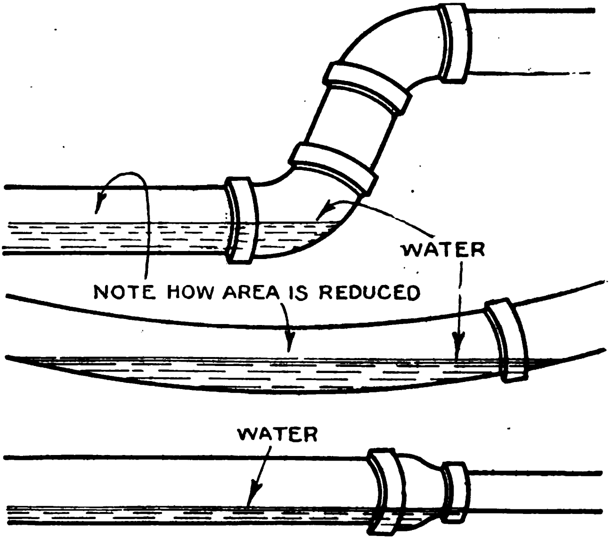


FIG. 5,338.—Method of by passing a trap. ***It is good practice,*** though not necessary except in special cases, to install each trap with a by pass, with valve on either side of the trap and in the by pass.

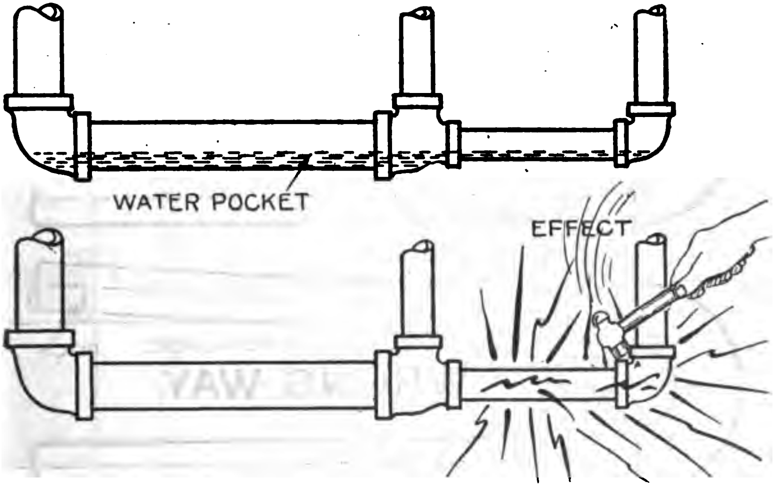


FIGS. 5,339 to 5,341.—Faulty piping methods. Fig. 5,339 shows a water pocket formed because of lack of pitch, and fig. 5,340, another pocket formed by sag in pipe. These pockets reduce the area available for the flow of steam with resulting loss in efficiency. Fig. 5,341 shows a water pocket formed by reducing without using an eccentric fitting.

Ques. How should the risers be connected to the steam mains, and why?

Ans. 45° elbows should be used so that the condensation will drain along the metal of the pipe and fittings instead of dropping directly into the steam, which would tend to saturate and cool the steam.

Figs. 5,333 and 5,334 show the right and wrong way of connecting risers to main.



Figs. 5,342 and 5,343.—"Water hammer" caused by using ordinary fittings on mains instead of eccentric fittings. In some instances (especially on long lines), a sudden rush of steam through the pipe will hurl the water against the elbow at the end with such violence as to fracture it, producing the same effect as though the fitting were struck a violent blow with a hammer.

Ques. Where the riser is connected direct to a drip pipe, how should it be connected to the main?

Ans. By a 45° elbow looking downward, as in fig. 5,335.

Ques. How are water pockets avoided in reducing the size of mains?

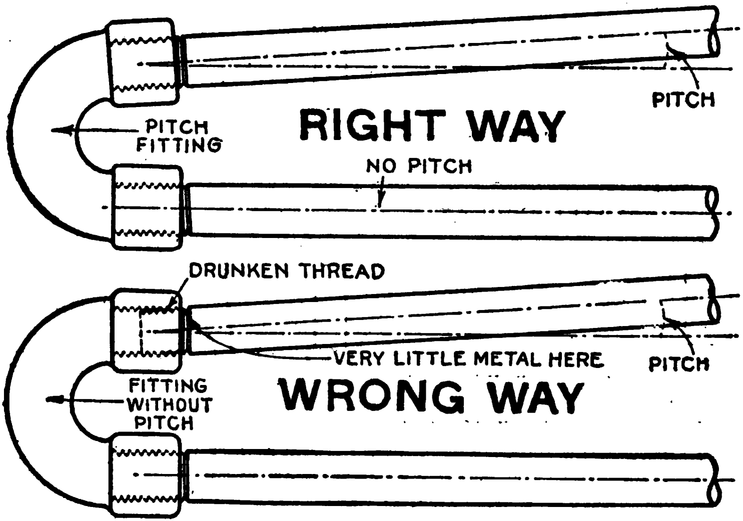
Ans. By the use of eccentric fittings, as in figs. 5,474 and 5,475.

Figs. 5,144 and 5,145 (page 2,859) show eccentric reducing tees.

Ques. Why is such precaution advisable?

Ans. Because a sudden rush of steam occasioned by opening a radiator might take up the water and project it with great velocity and force against any turn in the direction of the main, this effect being known as water hammer.

Ques. What trouble is sometimes encountered with radiators located at elevations near the level of the water in the boiler, and why?



FIGS. 5,344 and 5,345.—Right and wrong way of making up coils and lines where *pitch* is required for drainage. In first class work, "pitch fittings" are used to secure the proper inclination of a pipe, but on the usual botch job, an ordinary fitting is used and a "drunken thread" cut on the pipe. Evidently such method of threading not only gives a poor joint, but one which because of the deep cut on one side of the pipe is liable to leak in time by eating away of the thin metal due to corrosion. On heating jobs such work should be rejected.

Ans. On long lines where there is considerable reduction of pressure, the water sometimes backs up into the radiator, as in fig. 5,346, thus interfering with its operation.

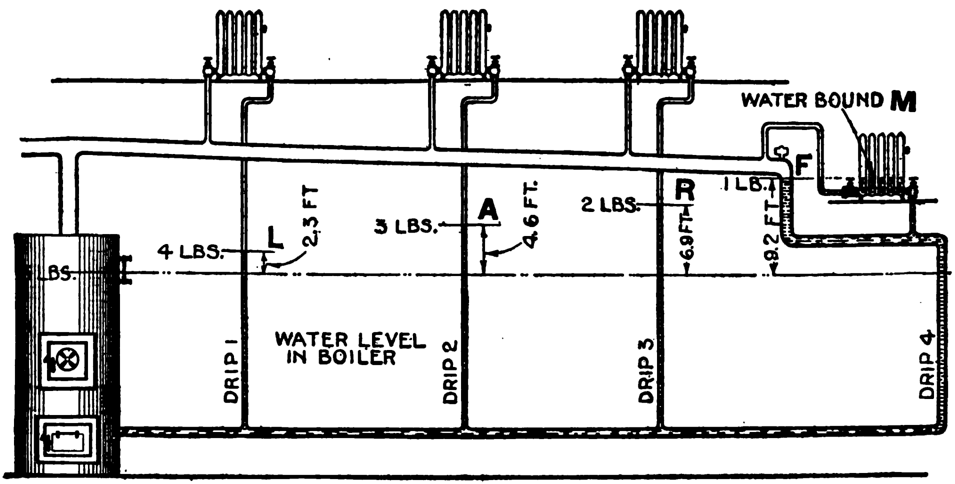


FIG. 5,346.—Water "backing up" in radiator on end of long line. Owing to pipe friction there is a gradual reduction of pressure in the main from the boiler to the end of the line, the water rising in the return pipes to gradually increasing elevations as **L**, **A**, **R**, **F**, to balance these pressure differences, the pressure difference being so great at radiator **M**, as to bring the water level **F**, in the return pipe high enough to partially flood the radiator. Hence, on the pressure differences at a remote point will depend the height at which the radiator must be placed to avoid this trouble. Water levels in return pipes (to save space) are not to scale.

Ques. How may radiators be operated at elevations below the water level in the boiler?

Ans. By means of a steam loop, as shown in fig. 5,348.

One Pipe Overhead System.—This arrangement is well adapted to tall buildings, because if the radiators were fed from the bottom, the risers would have to be excessively large. Instead of a steam main encircling the basement it is carried directly to the attic, forming a central riser for all the radiators. It branches in the attic to the drops or down flow supply pipes, which serve the various radiators as shown in fig. 5,347.

Since steam and condensation flow in the same direction in the down flow pipes and the riser contains only steam, these pipes can, as must be evident, be smaller than in the under connected system, as shown in fig. 5,331.

One Pipe Circuit System.—For a rectangular building of low or moderate height the steam main is conveniently carried entirely around the basement. Risers are tapped from the main at various points to serve the radiators. The main being inclined from beginning to end, the condensation drains in the same direction as the

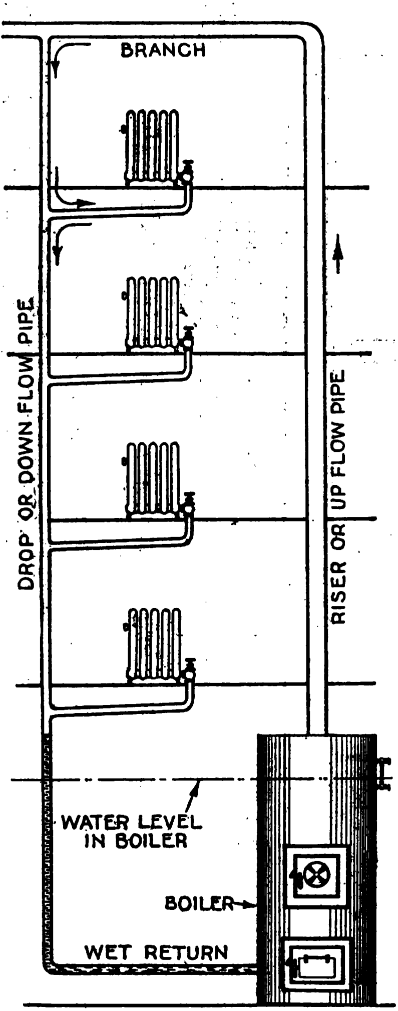


FIG. 5,347.—So called "one-pipe" overhead system as installed in tall buildings. Its features are uniflow of steam and condensation, which permits the use of smaller pipes.

steam flows, being carried to the drip pipe, thence into the boiler. Since there is no return pipe as with the relief system, the circuit arrangement is less expensive to install.

Fig. 5,350 shows the general arrangement of the system, it being the same as the relief system with exception of the steam main, and absence of a return.

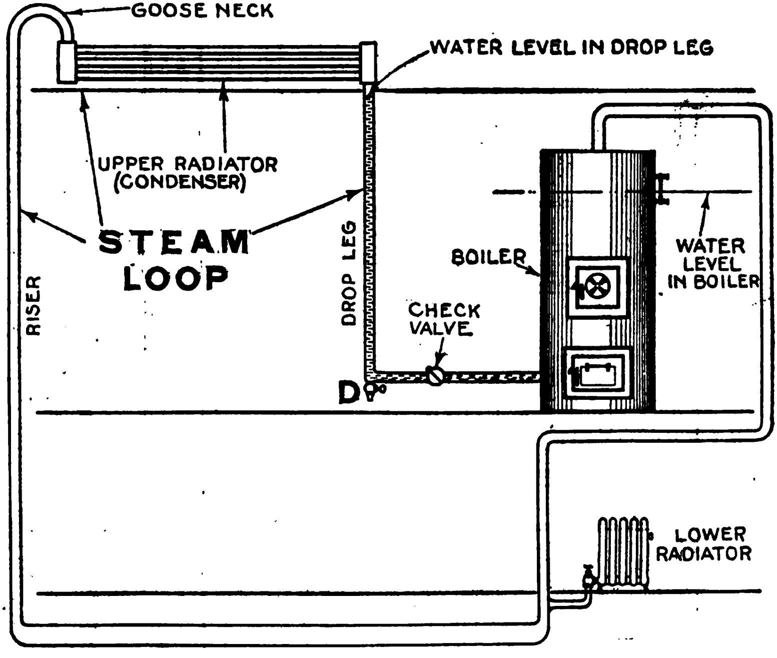


Fig. 5,348.—Steam loop method of operating radiator placed below level of water in boiler. In the steam loop the condenser element may consist of a pipe radiator placed on floor above boiler. The liberal condensing surface thus provided will render the loop very active in removing the condensation and at the same time the heat radiated from the condenser is utilized in heating. The drop leg is provided with a drain cock D, and the connection to boiler, with a check valve. ***To start the system,*** turn on steam at the boiler and open D, until steam appears. The condensation of steam in the condenser (upper radiator) will cause a rapid circulation in the riser, carrying with it the condensation from the radiator, which, in passing over the *goose neck*, cannot return, but must gravitate through the upper radiator and *drop leg* past the check valve and into the boiler. The pipe at the bottom of the main riser which acts as a receiver for the condensate from the lower radiator, should be one or two sizes larger than the pipe in the main riser.

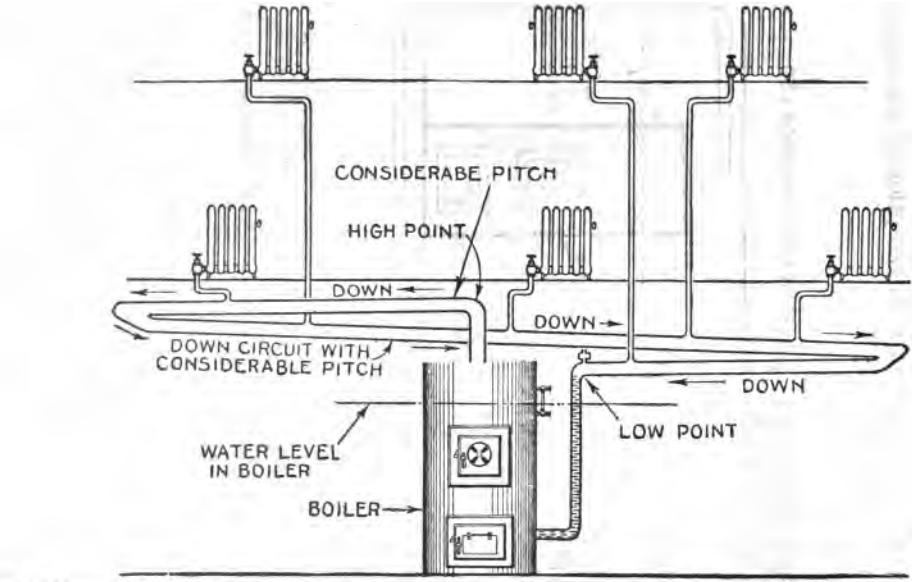


FIG. 5,350.—One-pipe circuit system. Since there is no relief, the condensation must traverse the entire circuit of the steam main, hence it must be given considerable pitch. It is not necessary that the pitch be uniform but, as must be evident, it should increase after each riser tap. Where there is little head room this will prove the more efficient arrangement. The diagram shows the general features of the system.

One Pipe Divided Circuit System.—This arrangement is suited to long buildings with boiler located near the center, the circuit being divided at A, fig. 5,351, that is, each end is connected to a drip pipe connecting with a return, giving separate seals for each end.

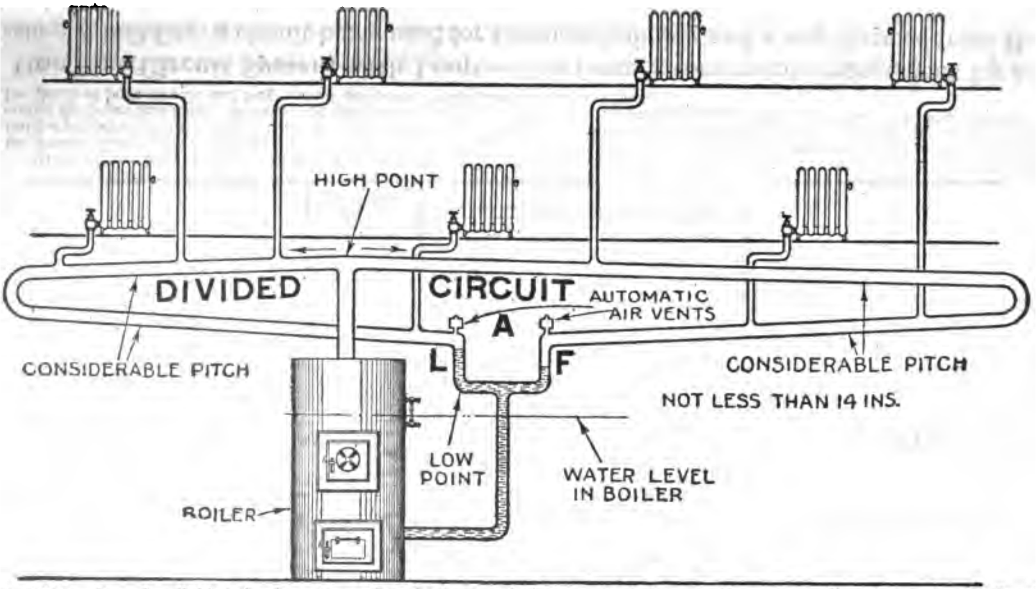


FIG. 5,351.—One pipe divided circuit system. Suitable for long buildings with boiler near the center. Since two paths are offered for the steam to the risers, evidently the size of the main can be less than where the entire flow passes through a single line; this then is a saving in installation. Moreover, for unequal distribution of the radiation, the main can be proportioned accordingly, reducing the cost of piping to a minimum. Automatic air vents should be placed at the end of each arm, as shown.

For proper operation these ends should not be at a less elevation than 14 inches above the boiler water level. The individual seals make the two halves of the divided circuit independent, which is desirable for unequal loads. Thus there may be considerable difference between the pressure at L, and F, each being what is necessary to balance the load.

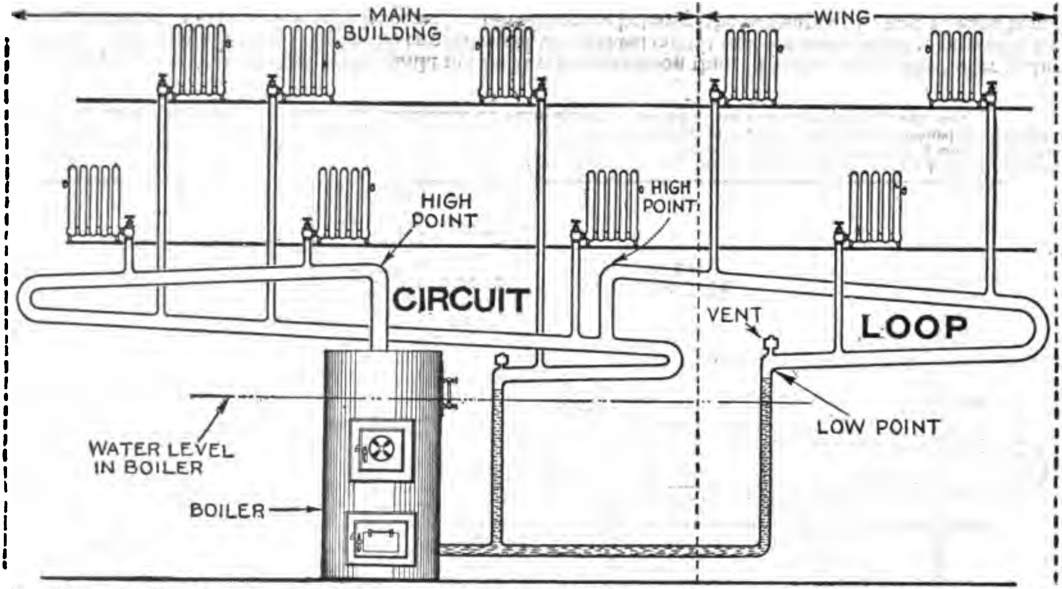


FIG. 5,352.—One-pipe circuit system with loop suitable for L-shape buildings, the circuit serving the main building, and the loop, the wing. There are two high points in the steam main piping, thus both circuit and loop may have ample pitch (which is essential for proper drainage), without undue head room. The circuit leads directly to the boiler, but a return is placed between the end of the boiler and loop. Both circuit and loop should be provided with an automatic air valve as shown. For ideal conditions **the pitch of both circuit and loop should be increased at each riser connection.**

One Pipe Circuit System with Loop.—This forms a convenient arrangement for an L-shaped building, a circuit being used for the main building and a loop (tapped from the circuit), serving the wing.

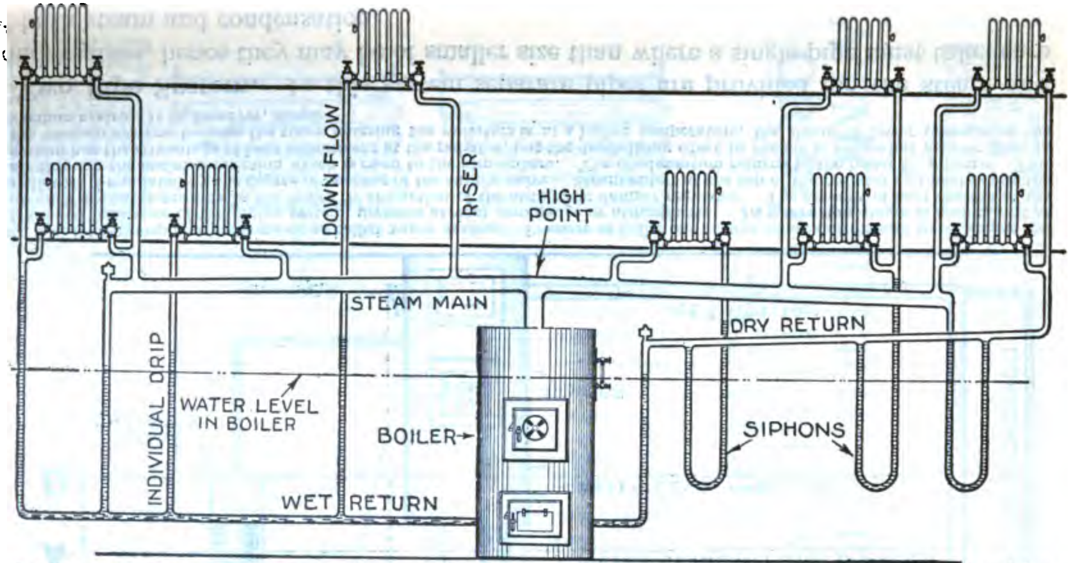


FIG. 5,353.—Two pipe system. Steam and return mains are employed the same as with the one pipe system. Various piping arrangements are used for these, such as circuit, divided circuit, loop, etc., as will best meet the requirements of the buildings. Dry or wet returns may be used. Steam is supplied to the radiators through risers and the condensation returned through down flow or drip pipes, as shown. Smaller pipes for both risers and down flows are used than in the one pipe system, the cost notwithstanding is greater than for the one pipe system, hence the popularity of the latter.

In this system there will be two high points; one at the beginning of the circuit and the other at the beginning of the loop, thus giving ample margin above the boiler water line for liberal pitch in both the circuit and loop. Fig. 5,352 shows the general features of the system.

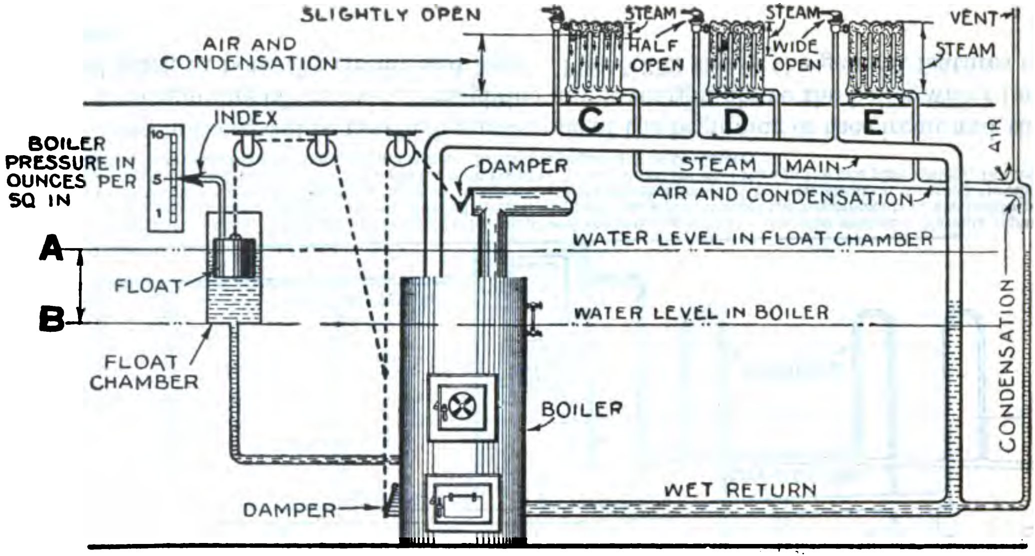
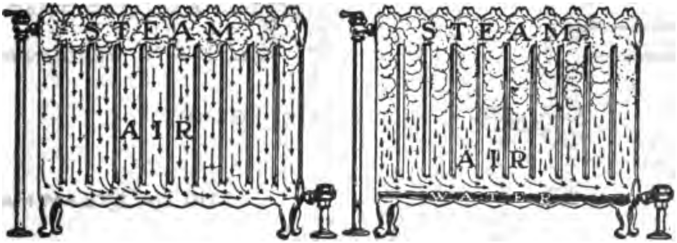


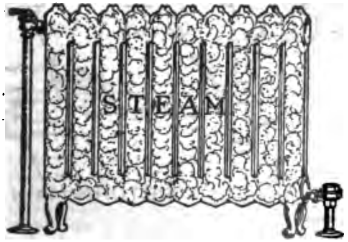
FIG. 5,354.—Atmospheric pressure or so called vapor system. Pressure at boiler one to five ounces or enough to overcome the frictional resistance of the piping system; pressure at vent zero gauge or atmospheric. *In operation* steam is maintained at about five ounces pressure in the boiler by the action of the automatic damper regulator. The amount of heat desired at the radiators is regulated by the degree of opening of the supply valve. Steam enters at the top of the radiator and pushes out the air through the outlet connection which is open to the atmosphere. The condensation returns to the boiler by gravity. This system has the advantage of heat adjustment at the radiator, but the devitalizing effect in the air is somewhat greater than in the vacuum systems because the steam entering the radiators is at a higher temperature, the steam of lower pressure in the vacuum system. It is, however, simple.

Two Pipe System.—In this system separate pipes are provided for the steam and condensation, hence they may be of smaller size than where a single pipe must take care of both steam and condensation.

Any arrangement of the steam and return main, such as the relief circuit, divided circuit, etc., may be adopted to suit the requirements of the building. Risers are connected to the steam main at suitable points to serve the radiators, and down flow or drip pipes connect the radiator outlets with the return main, as shown in fig. 5,353.

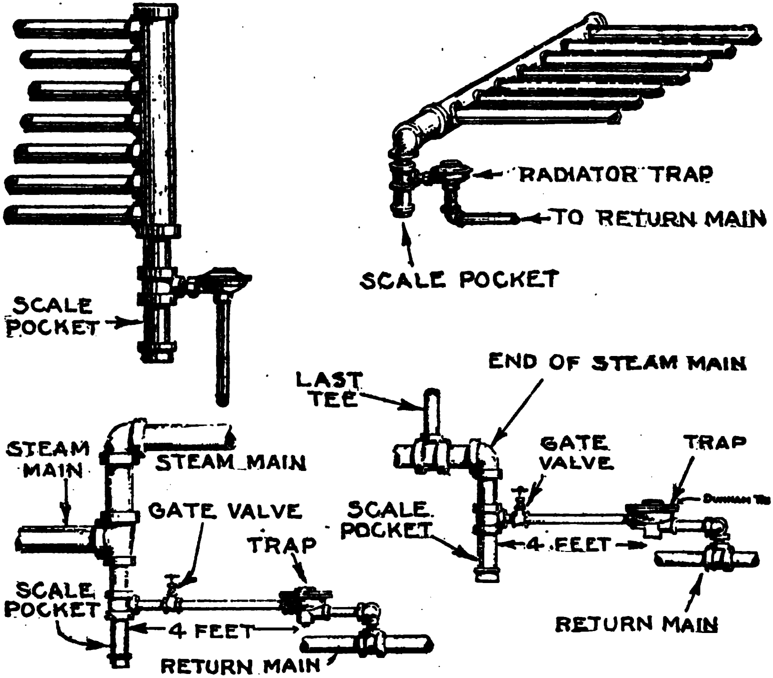
ATMOSPHERIC PRESSURE OR SO CALLED "VAPOR" SYSTEMS





FIGS. 5,355 to 5,357.—Operation of down flow vapor-vacuum radiators. Fig. 5,355, steam entering, air passing out through thermostatic retainer valve; fig. 5,356, more steam entering, condensation and balance of air passing out through trap; fig. 5,357, radiator full of steam, thermostatic retainer valve closed. As steam enters a cold radiator it forces the cool air which is in the radiator out through the trap into the return piping. In warming the radiator, the steam gives off heat and in doing so condenses to water. The water which is heavier than steam falls to the bottom of the radiator and flows to the trap through which it also passes into the return piping. After forcing out the air the steam fills the radiator and follows the water to the trap which in the presence of steam automatically closes because the steam is hotter than either the air or water. The heat of the steam expands the valve control element, closing and holding the valve against its seat with a positive pressure, thus trapping the steam within the radiator. The radiator now thoroughly filled with steam gives off heat condensing the steam at a uniform rate and the water of condensation which is cooler than the steam flows in a steady stream to the trap which it slightly chills causing it to open allowing the water to pass out. The trap adjusts itself to a position corresponding to the water temperature just as a thermometer does to the room temperature, and permits a continuous flow of water from the radiator.

If manufacturers of special steam heating systems working at atmospheric, or less than atmospheric pressure, would stop trying to appear learned by using such studied terms as *fractional control*, *modulation*, *thermo-seal*, **vapor**, *syphon*, etc., etc., in describing their apparatus, and get down to plain English, so as



FIGS. 3,358 to 5,361.—Dunham piping suggestions for traps. Fig. 5,358, trap used on wall coil; fig. 5,359, trap used on ceiling coil; fig. 5,360, trap used on deep end of steam main; fig. 5,361, trap used to disperse in steam main. ***In applying***, traps to pipe coils they should be installed as here shown. ***A scale pocket** should be provided at the bottom of the return header and in front of the trap*. When a trap is used for dripping steam piping it should be installed with at least four feet of connecting piping between it and the point dripped. A liberal scale pocket should be provided also a valve in the connection to the trap. When used for dripping the end of a steam main, the latter should enter beyond the last used connection and be provided with a full sized scale pocket. A rise or jump up in a steam main is dripped as in fig. 3,360. Down feed risers require individual drips and traps.

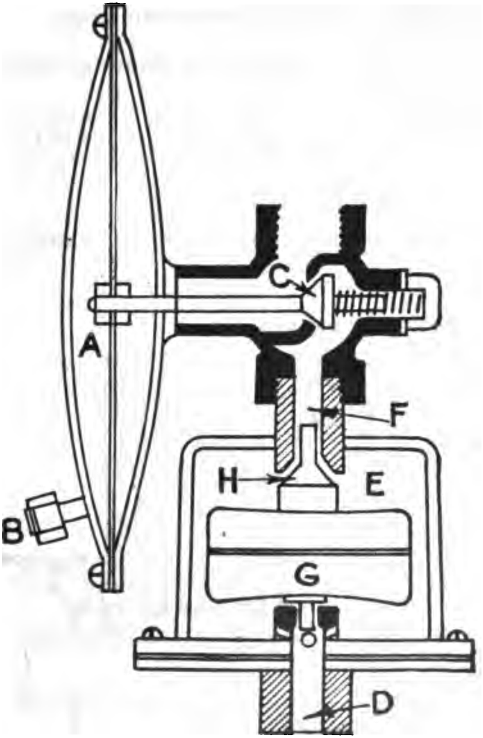


Fig. 5,362.—Dewey tri-duty air and vacuum trap as used on the Imico combined atmospheric pressure and vacuum system. This trap is placed on the return line not less than 27 ins. above water line. Diaphragm A, is attached to pressure main by small copper tube at B, nominally valve C, stands closed and held to seat by light coil spring. When fire is started in heater, air is expanded and inflates diaphragm A, and opens valve C, which remains open as long as there is any pressure on boiler. The steam passes into radiators at the top forcing air into return line and out through opening D, into float chamber E, passing into opening F, and through valve C, to atmosphere. Modulating valves are used on the radiators. If steam pass through radiators and into return line and into float chamber E, expanding thermostatic float G, closes valve H. If the steam pressure run up to a point high enough to force water up the return line to the trap, water passes into float chamber E, and raises the float G, and closes valve H. When the steam goes down, valve C, is forced to seat by coil spring and vacuum is formed by condensation in the radiators and drawing the vapor through the system until the temperature is too low in heating system to cause circulation. Tnen when the fire is replenished and steam commences to be given off circulation is again established before any pressure is shown and when pressure rises the triduty air and vacuum trap functions as before.

not to mystify the ordinary public, their customers would no doubt be more enlightened and more numerous.

The term *vapor* as used, simply means **steam** *at approximately atmospheric pressure.*

Low pressure steam, vapor, and vacuum, as applied to heating, are merely relative terms, the first applying to pressures of 1 to 5 pounds; the second to pressures of 1 to 5 ounces, and the last to any pressure below atmospheric.

Fig. 5,354 shows an atmospheric pressure heating system.

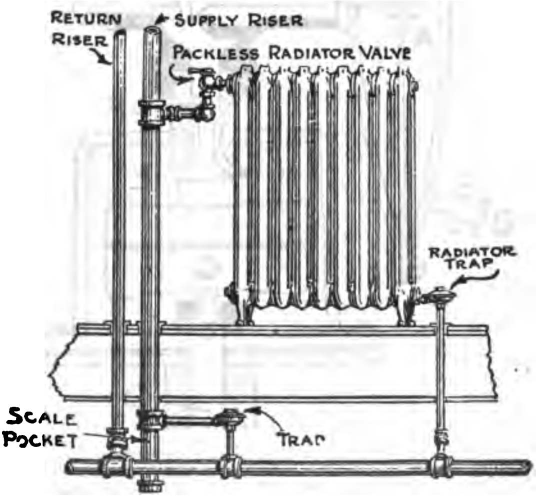
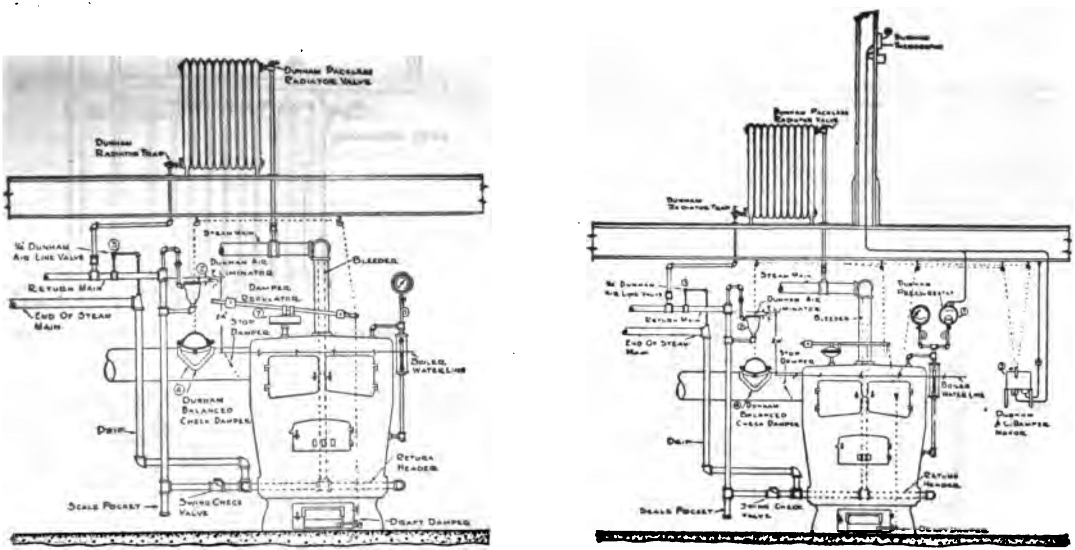
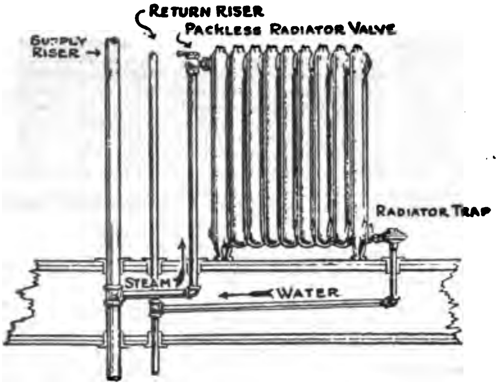


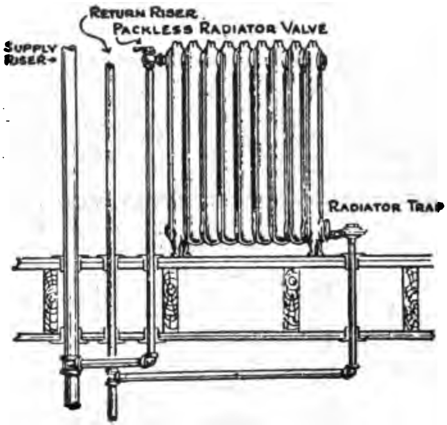
FIG. 5,363.—Dunham piping suggestions for radiator connections, radiator trap and traps used to drip a down fed riser.

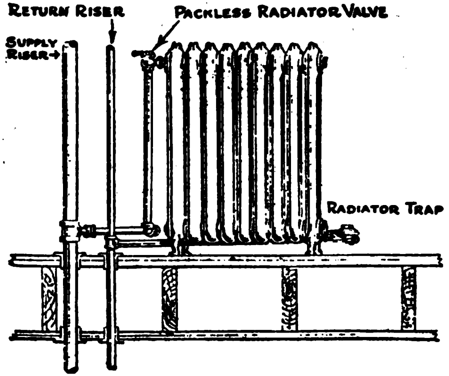
It should be understood that the term atmospheric pressure is only used for convenience, for in fact a pressure of about five ounces above atmospheric is carried on the boiler or sufficient to overcome the frictional resistance of the piping, and since the return connection of the radiators is open to the atmosphere, it can be readily understood that the success of the system depends on the proper working of the automatic damper regulator in keeping the boiler pressure within proper limits. To accomplish



FIGS. 5,364 and 5,365.—Dunham damper regulation. The steam pressure **is very low, not over 8 ounces or so called *atmospheric.*** Fig. 5,364 shows the diaphragm type regulator. ***In operation,*** the pressure within the boiler acts directly on the large diaphragm causing it to expand or contract as the pressure increases or decreases, and the draught and check dampers are closed or opened as required. Fig. 5,365 show an electric damper regulator sometimes used in place of the diaphragm type. The electric regulator consists of a "pressurestat," a thermostat, and a damper motor. The motor may be of three types—spring, *d.c.*, or *a.c.* electric motor. The pressurestat is located at the boiler; its function is to control the steam pressure, operating the damper motor, as occasion requires, to make it move the draught and check dampers. The thermostat which is operated by the temperature of the room in which it is located controls the draught in conjunction with the pressurestat through the damper motor. Only one thermostat and pressurestat can be used with one heating plant.







FIGS. 5,366 to 5,368.—Dunham atmospheric system piping methods. Fig. 5,366, pipes between floor and ceiling; fig. 5,367, pipes below ceiling; fig. 5,368, pipes above floor. Angle pattern traps with suitable connection are preferable although the Dunham Trap can be supplied in the corner and straightway patterns when necessary. Hot water type radiation with top inlet tapping is recommended. It is of importance in applying Dunham Traps to their several uses to properly grade the units or piping to be dripped toward the trap and the return piping away from the trap. All piping must be free from sags or pockets.

this the dampers are controlled by a float working in a float chamber in communication with the water space in the boiler as shown.

When the pressure in the boiler is the same as that of the atmosphere, that is, zero gauge pressure, the water level in the float chamber is the same as that in the boiler and the index hand points to zero.

Now in generating steam as the pressure increases, the water level in the boiler is forced downward, which causes the level in the float chamber to rise until the pressure due to the difference AB, of water levels balances that in the boiler.

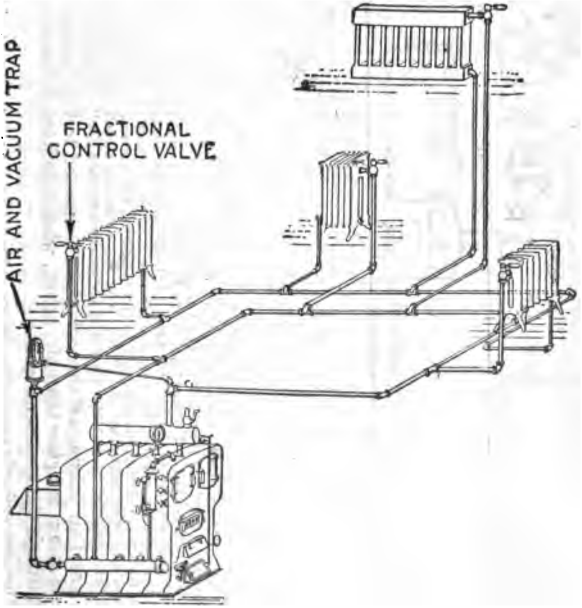


Fig. 5,369.—Imico combined atmospheric pressure and vacuum system showing proper method of installing the Dewey tri-duty air and vacuum trap.

The float in rising, since it is connected by pulleys and chains to the dampers, closes the ash pit damper and opens the stack damper, thus checking the draught and preventing the further increase of steam pressure. Steam is distributed to the radiators through the usual risers, which, however, with this system are connected to the radiators at the top as shown in the

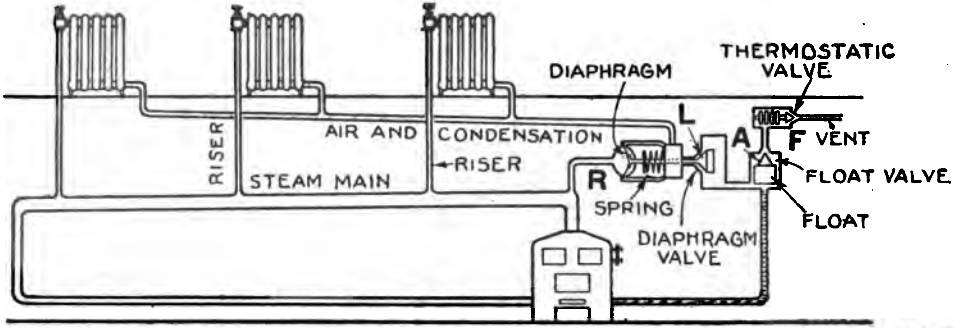


FIG. 5,370.—**Combined atmospheric-pressure and vacuum.** **Pressure in the boiler** is obtained from one to five ounces above atmospheric pressure, which is needed to operate the diaphragm regulator until air is expelled and the complete system filled, it being then "throttled" by the radiator supply valves while giving the desired vacuum in the radiators. ***In operation,*** when steam is raised in the boiler it passes through the steam main, risers and supply valves to the radiators. The proper working of the system is obtained by an automatic device or trap which closes against the pressures of either steam or water and allows air to pass out, but not return. This device, as shown, consists of three elements: diaphragm valve **L**, float valve **A**, and thermostatic valve **F**. There is a connection **R**, from the supply pipe or pressure side of the boiler to the diaphragm and when there is no pressure in the boiler this valve is held shut by a spring. When the fire is started and the air in the boiler is expanded, the diaphragm is inflated and opens the vacuum valve, making a direct opening through valves **A** and **F** (which under this condition are also open) to the atmosphere. The valve **L**, remains open as long as there is a fraction of an ounce pressure on the boiler. Now, as steam forms and passes through the system it drives all the air out through the three open valves, **L, A, F**, but when the steam on its return from the system reaches the thermostatic valve **F**, the heat causes it to expand and close, thus the system is filled with steam only. The vacuum is now obtained on the principle that the steam admitted into the radiators condenses, while transmitting its heat through the radiator and shrinks considerably (each cu. ft. of steam being approximately reduced in volume to 1 cu. in.). If by too much throttling of the steam supply to the radiators, the vacuum should become strong enough to draw up water in the return pipe too high, the float rises and closes valve **A**, remaining closed until the water recedes, then it opens allowing valve **F**, to expel any air that may be in the system and the process repeats itself automatically.

figure, the condensation and air passing off through pipes connected to the *bottom* of the radiator. The reason for this is because steam is *lighter* than air, hence, when admitted it floats on top of the air, thus driving the latter out through the lower connection.

The chief feature of the atmospheric pressure system is that the amount of heat given off by each radiator may be regulated by the steam valve (so called fractional control, modulation valve, etc.). Thus, in fig. 5,354, the valve of radiator C, is opened just a little, which will admit only just enough steam to heat the upper portion of the radiator; the valve of D, is half opened, admitting enough steam to heat a larger portion of the radiator; with valve wide opened on E, the entire radiator is heated.

COMBINED ATMOSPHERIC PRESSURE AND VACUUM SYSTEM

The object sought in vacuum heating is to avoid devitalizing the air by using steam in the radiators at pressures *less* than atmospheric, thus reducing the temperature to which the metal of the radiator is heated. For instance, the temperature of steam at atmospheric pressure is 212° Fahr., and at say 5 pounds absolute pressure, which corresponds to a 19.7-inch vacuum, it is only 162° Fahr.

In the combined atmospheric pressure and vacuum systems, the pressure in the boiler is maintained at from one to five ounces above atmospheric pressure, which is needed to operate the damper regulator, it being "throttled" by the radiator supply valves to give the desired vacuum in the radiators. The working principles of such systems are shown in fig. 5,370.

In operation when steam is raised in the boiler it passes through the steam main, risers and supply valves to the radiators.

The proper working of the system is obtained by an automatic device or trap, which closes against the exit of either steam or water, and allows air to pass out, but not return. This device, as shown in fig. 5,370, consists of three elements: diaphragm valve L, float valve A, and thermostatic valve F. There is a connection R, from the supply pipe or pressure side of the boiler to the diaphragm, and when there is no pressure on the boiler this valve is held shut by a spring.

When the fire is started and the air in the boiler is expanded, the diaphragm is inflated and opens the vacuum valve, making a direct opening through valves A, and F, (which, under this condition are also open), to the atmosphere. The valve L, remains open as long as there is a fraction of an ounce pressure on the boiler.

Now as steam forms and passes through the system it drives all the air out through the three open valves L, A, F, but when the steam reaches the thermostatic valve F, the heat causes it to expand and close, thus the system is filled with steam only.

The vacuum is now obtained on the principle that the steam admitted into the radiators condenses, while transmitting its heat through the radiator and shrinks considerably (each cubic foot of steam being approximately reduced in volume to 1 cubic inch).

If by too much throttling of the steam supply to the radiators, the vacuum should become strong enough to draw up water in the return pipe too high, the float rises and closes valve A, remaining closed until the water recedes, then it opens, allowing valve F, to expel any air that may be in the system.

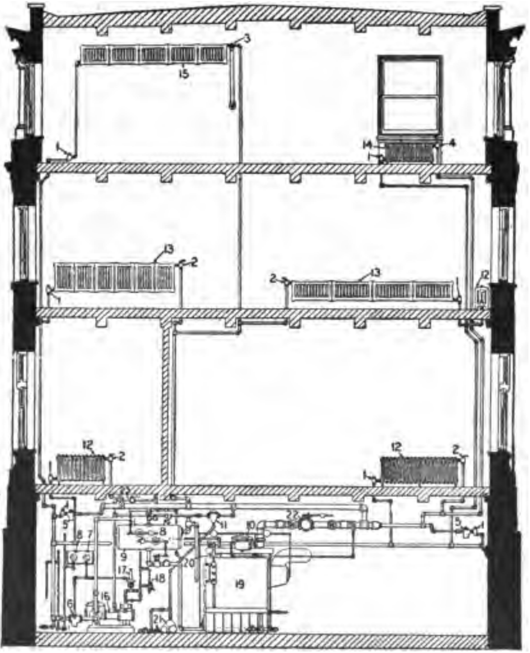


FIG. 5,371.—General arrangement of Webster "Pres-co" vacuum system. ***The parts are:*** 1, syphon trap; 2, modulation valve; 3, modulation valve with chain attachment; 4, modulation valve with extended stem; 5, dirt strainer; 6, suction strainer; 7, vacuum gauge; 8, pressure gauge; 9, hydro-pneumatic tank; 10, damper regulator; 11, oil separator; 12, standard column radiator; 13, wall radiator; 14, window radiator—recessed; 15, overhead wall radiator; 16, vacuum pump; 17, vacuum pump governor; 18, vacuum pump lubricator; 19, boiler; 20, boiler gauge; 21, grease trap; 22, pres-co valve; 23, back pressure valve.

VACUUM SYSTEMS

In order to compete with hot water heating systems which, because of the low working temperature, do not devitalize the air, various steam systems working at pressures below that of

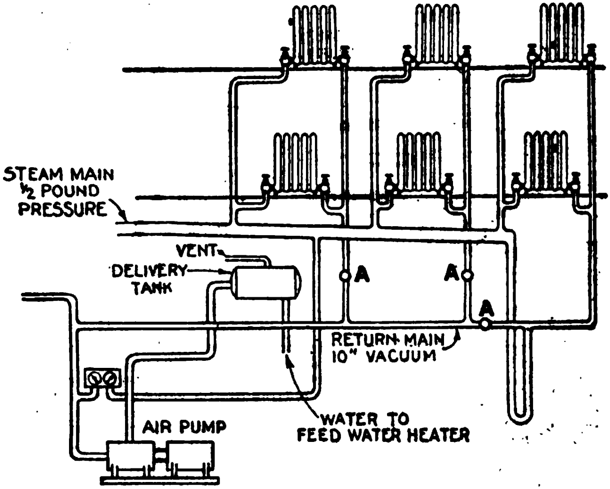
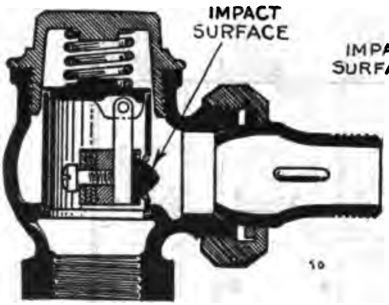


Fig. 5,372.—Differential Co. vacuum return line system showing application of differential and impulse valves. In the installation shown there are three differential valves located in the return risers at A. They are weighted to open at about five lbs. difference in pressure, and as there are a number of radiators in each group, an impulse check valve is placed on the return end of each radiator. ***In operation,*** the vacuum pump is started and the air is exhausted from the return line until a vacuum of 10 inches is produced. This causes the three differential valves in the branch returns to open, and establish a substantially uniform flow through each into the main return. As the air in the pipe between the differential valves and the radiators is exhausted, the impulse check valves on all radiators will open and a uniform flow is thereby obtained from each of these into the branch returns. In accordance with the location of each of the differential check valves, the weights in them are adjusted to compensate for changes in pressure due to the friction of flow in the steam and return mains up to that point, and thereafter no part of the apparatus will require any attention. No jet water is required or necessary at the vacuum pump, and the amount of vacuum carried may be fixed at any point by putting the correct weights in the differential check valves. The degree of vacuum maintained on the return line, or the difference in pressure between the steam and return line, is established and maintained at any predetermined amount by the adjustment of the differential valves. Therefore, a vacuum governor should not be used to regulate the vacuum pump. If the vacuum pump be of sufficient capacity and the main return is tight, the desired vacuum will be maintained by the pump operating at minimum speed.



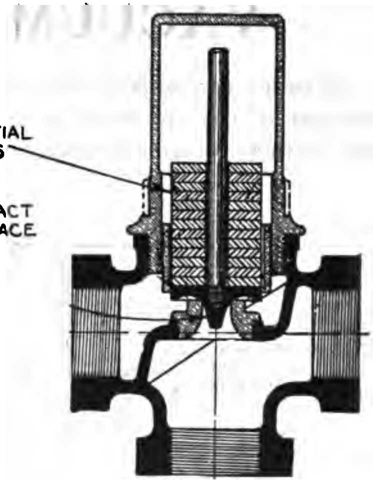


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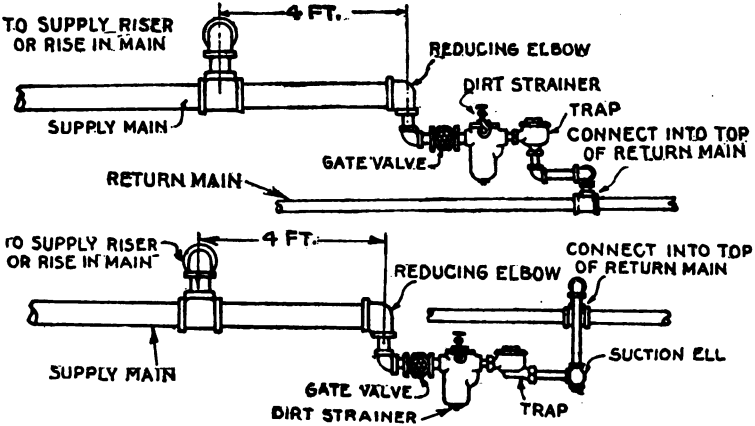
FIG. 5,373.—Differential Co. *impulse* valve for vacuum return line system. ***It consists of*** a heavy brass cylinder inserted in a standard valve body. This cylinder fits into a counterbore which is cut to receive it, and is held firmly in place by a strong spring. A seat is provided in the side of the cylinder, close to the bottom, and a valve piece is swung from above in the same manner as is usual in swing check valves. The valve disc is provided with an impact surface upon which the water of condensation strikes, thereby opening the valve to its full capacity. The seat of the impulse valve is made much smaller than that of an ordinary check valve, so that it will properly control the flow of water and steam from the radiator and prevent short-circuiting. The weight of the impulse valve disc over the area of the seat, as well as the restriction of the orifice, are both so proportioned that the pressure in the branch return lines is from one-quarter to one-half pound lower than the pressure in the steam main, irrespective of the pressure carried. ***In operation,*** when the supply valve of the radiator is closed, the impulse check valve prevents any water or steam entering the radiator from the return.

FIG. 5,374.—Differential Co. *differential* valve for vacuum return line system. ***It is made*** with a standard safety valve body and has a restricted orifice through the seat which is proportioned to the desired capacity of the valve. The valve disc in this, as well as in the impulse valve, is provided with an impact surface upon which the water of condensation strikes in order that the valve shall be opened to its maximum capacity when water is passing. The valve disc is also provided with a central rod and cup shaped portion for holding the weights by which the desired difference in pressure is obtained and regulated. The area of the seats, and the weights in all sizes of valves, are proportioned so that the brass cup will give about three inches of vacuum and each lead weight one inch additional. The opening in the bottom of the valve is intended as a clean out and should be provided with a nipple and cap. All condensation should flow by gravity to the differential check valve, but it may then be lifted to the maximum height permissible by the vacuum carried. A small leakage opening is provided in the seat of the differential valve so that the system will drain when the plant is shut down.



FIGS. 5,375 and 5,376.—Diagrams showing method of connecting Bishop and Babcock vacu-trap on drip points of the return line vacuum system. Fig. 5,375, where return main is below supply main; fig. 5,376, where return is on same level or above supply main.

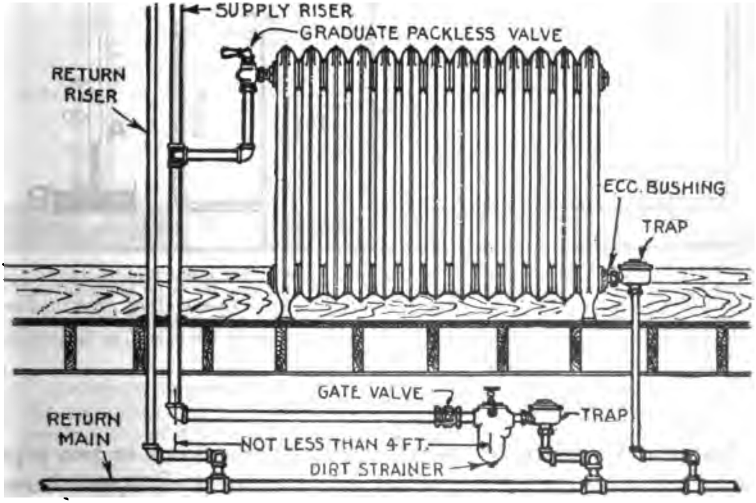


FIG. 5,377.—Typical method of connecting thermostatic valve or so called "vacu-trap" on drip at base of a down feed riser for hot water type radiator as used with Bishop and Babcock return line vacuum system of steam circulation. Drip connection below flow.

the atmosphere have been devised, and are known as vacuum systems. These may be divided into two general classes, according to the method of producing the vacuum, as

1. Natural vacuum, by
   - *a.* Mercury seal.
   - *b.* Thermostatic valves.
2. Mechanical vacuum, by

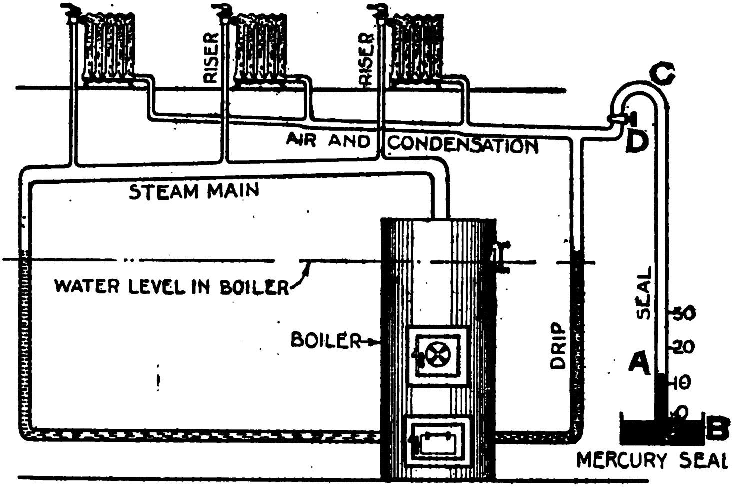


FIG. 5,378.—Natural vacuum mercury seal system. The air line is provided with a valve D, just beyond the drip, and loop C, leading to the mercury seal, the latter being virtually a barometer composed of mercury tube A, and mercury cup B. *In operation*, when the pressure is above atmospheric pressure, the air is forced out by bubbling through the mercury in the cup B, and when there is vacuum, the mercury rises in the tube A, to balance the vacuum.

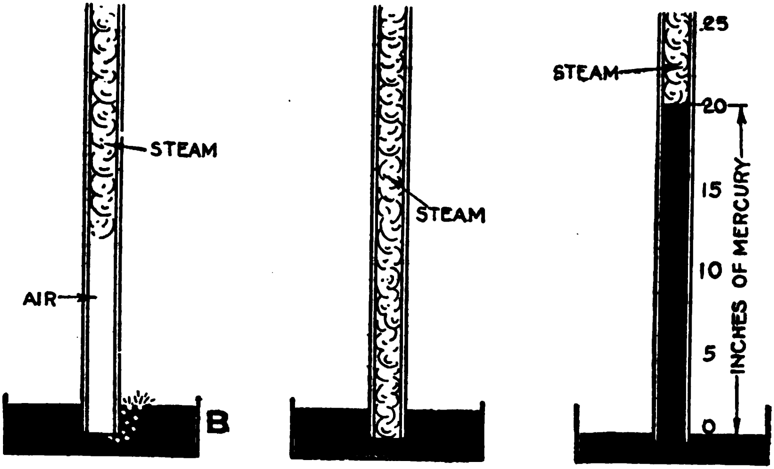
   - *a.* Ejectors.
   - *b.* Air pumps, etc.

Natural Vacuum Systems.—Any standard one or two pipe steam system may be converted into a natural vacuum system by replacing the ordinary air valve by a "mercury seal" or connecting thermostatic valves to the radiator return outlet on radiators and providing a damper regulator to the boiler adapted to vacuum working.

The mercury seal system shown in fig. 5,378, is about the simplest arrangement.

The mercury seal, which is virtually a barometer, consists of a tube A, which dips just below the surface of mercury in cup B.

When steam is raised in the boiler to a pressure above atmospheric, it drives all the air out of the system, the air leaving by bubbling through the mercury in cup B. If the fire be then allowed to go out, the steam will condense and produce an almost perfect vacuum, provided all pipe fitting has been carefully done and the stuffing boxes are tightly packed.



FIGS. 5,379 to 5,381.—Operation of mercury seal. Air being heavier than steam, is blown out by bubbling through the mercury in the cup B, fig. 5,379, all the air being expelled in fig. 5,380. Now when the fire is checked the condensation in the radiators produce a vacuum causing the mercury to rise in the seal pipe as in fig. 5,381, to a height corresponding to the degree of vacuum.

Evidently by providing the boiler with proper automatic draught control, the apparatus may be operated at any desired degree of vacuum, say 4 or 5 pounds absolute (21.8 and 19.7 inch vacuum), and have the water boiling at temperatures as low as 153 to 162 degrees F.

A loop at C, prevents water being carried over into the seal pipe when purging the system of air.

If air should re-enter the system through leaks it may be again expelled by raising the steam pressure above atmospheric. As applied to residence heating, the plant may be operated during the day at several pounds gauge pressure by closing valve D, and when fires are banked for the night this valve may be opened and the system worked under vacuum.

The flexibility of vacuum systems is in sharp contrast with low pressure systems where steam disappears from the radiators as soon as the temperature drops below 212 degrees.

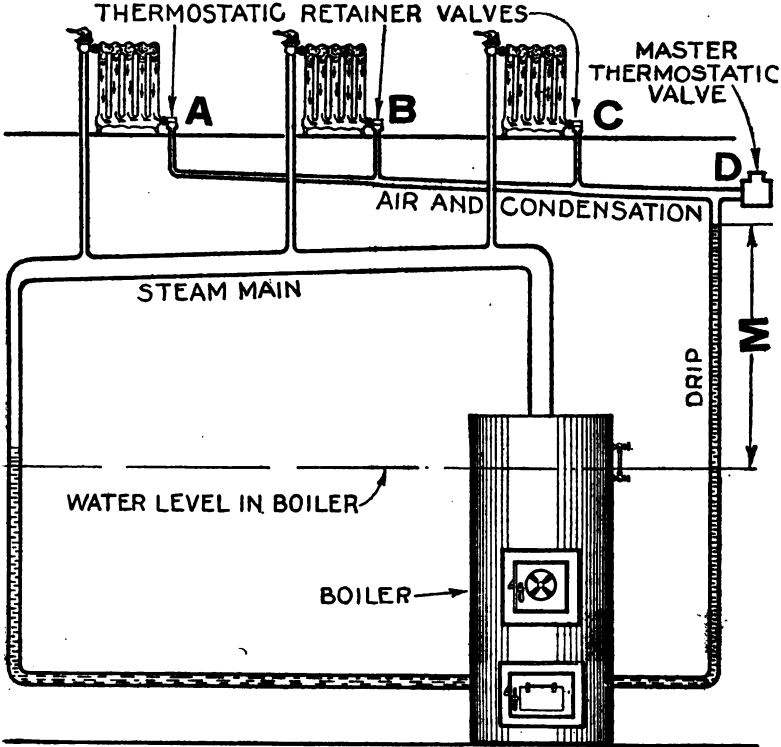


FIG. 5,382.—Natural vacuum system with retainer and master thermostatic valves. Individual thermostatic valves A, B, C, are placed on the outlet of each radiator which pass air or water, but close to steam. At the end of the air line is a master thermostatic valve D, which operates when the system is purged of air by excess pressure. The vertical distance M, between water level in boiler and lowest point of air line should be not less than two feet for each inch of vacuum to be carried in the system.

According to weather demands, the radiators may be kept at any temperature from say 150 degrees to 220 degrees. Figs. 5,379 to 5,381 show in detail the principle of operation of the mercury seal.

Instead of a mercury seal the same effect may be obtained by the use of thermostatic valves. In the usual arrangements, an individual thermostatic "retainer" valve is placed on each radiator and a master valve at the end of the air line, as in fig. 5,382.

The object of the retainer valves is to automatically allow the discharge of the air and water without letting the steam pass through; the master thermostatic valve retains the vacuum in the air line.

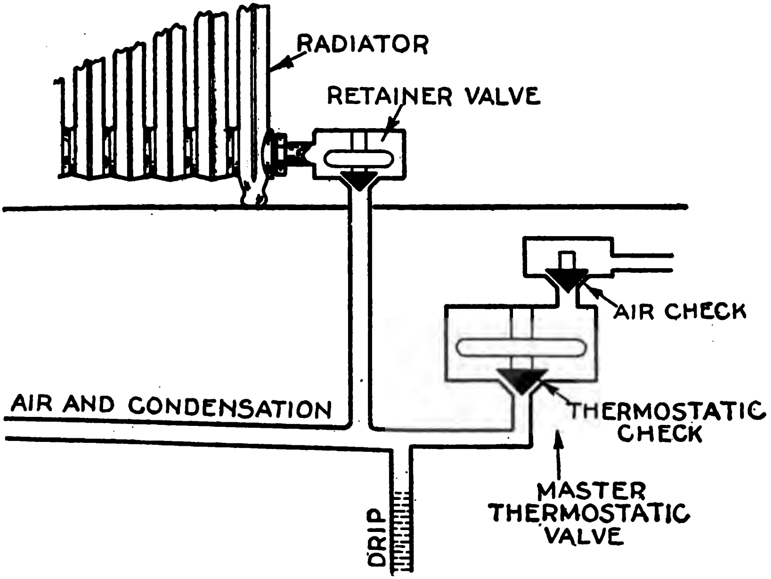


FIG. 5,383.—Detail of natural vacuum system with retainer and master thermostatic valves showing sectional views of the valves. The retainer valves are thermostatic in their action and are used to retain the vacuum in individual radiators. The master thermostatic valve is a purge valve used to clear the system of air and is of the same construction as the retainer valves but has in addition a poppet check valve on top which remains closed as long as the pressure in the system is less than atmospheric.

Fig. 5,383 shows in detail one of the retainer valves and the master valve. The latter has in addition to the expanding element, a ground seat poppet check at the top that is practically air-tight and will retain the vacuum within the system for a considerable time. This valve operates when excess pressure is generated in the boiler to purge the system of air, the check at other times remaining closed.

Draught Control on Natural Vacuum Systems.—The successful operation of natural vacuum systems depends largely on

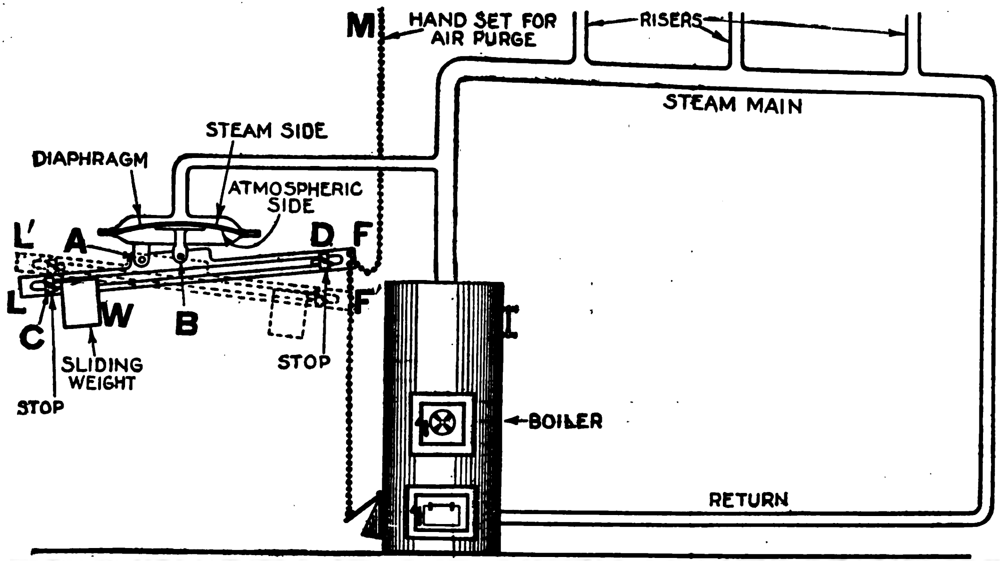


FIG. 5,384.—Damper regulator for natural vacuum system operating on the pressure principle. *In starting*, the diaphragm lever is placed in position LF, with weight at left, damper open. When pressure comes on the boiler it trips the lever to dotted line position, L′F′, weight slides over to right, and damper closes. The checking of the fire causes a vacuum to form, and as it increases, the upward pull on the diaphragm (equal to pressure difference on the two sides of the diaphragm) raises the right end F, of the lever and opens the damper, assuming some intermediate position depending upon the position of the weight as regulated by the stop D. That is, to increase vacuum move D, toward F; to decrease, move it toward L.

efficient damper regulators, for unless the fire be held in proper check, the pressure will rise and break the vacuum. Now, this wastes fuel, for there may be sufficient heat in the boiler to supply steam to the system with a five, or even a ten-inch vacuum, and hold that heat in the system for hours. Automatic damper regulators are designed to act by

1. Pressure,
2. Temperature,

or a combination of these two agencies.

Fig. 5,384 shows a regulator which acts on the pressure principle or rather difference of boiler and atmospheric pressure.

It consists of a diaphragm connected at B, to a lever fulcrumed at A, and having a weight W, free to slide along a slot between the stops.

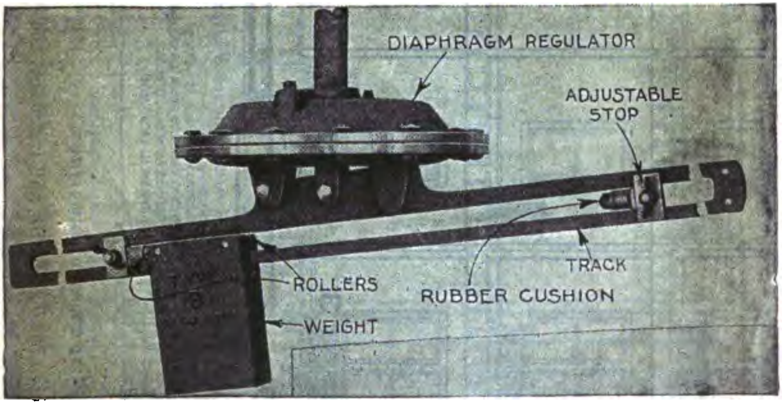


Fig. 5,385.—Roberts-Hamilton type B, diaphragm regulator for natural vacuum system, showing construction of the type shown in the diagram, fig. 0,024.

In starting the weight is placed on the left side of the lever, as shown, which tilts the lever (position LF), and opens the damper. The weight is adjusted by the stop so that sufficient pressure is produced to clear the system of air before the regulator trips to position L′F′ (shown in dotted lines), and closes the damper.

As the pressure comes on, it will be noted that the regulator is gradually closing, and when entirely closed, the weight slides to the right and remains in this position until the vacuum in the system becomes strong enough to gradually open the damper—just enough to maintain a vacuum.

In the morning the regulator may be set to open position from the floor above by the pull chain M. This generates pressure and purges the system of any air which might have accumulated, and then the regulator weight

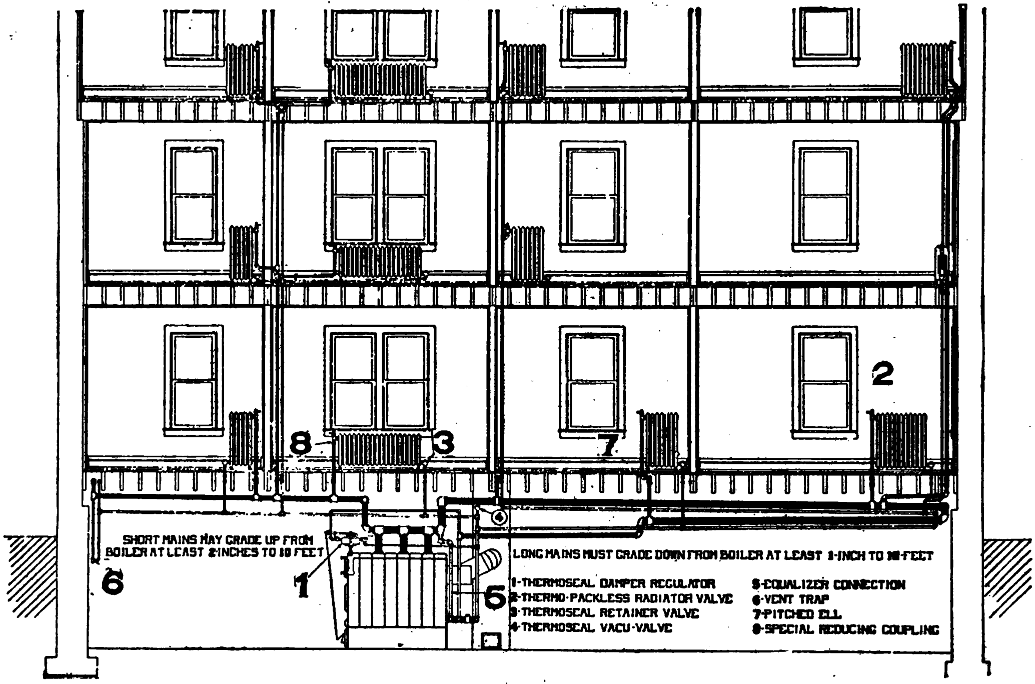

SHORT MAINS MAY GRADE UP FROM BOILER AT LEAST 2-INCHES TO 10 FEET
LONG MAINS MUST GRADE DOWN FROM BOILER AT LEAST 1-INCH TO 10-FEET
1-THERMOSEAL DAMPER REGULATOR
2-THERMO-PACKLESS RADIATOR VALVE
3-THERMOSEAL RETAINER VALVE
4-THERMOSEAL VACU-VALVE
5-EQUALIZER CONNECTION
6-VENT TRAP
7-PITCHED ELL
8-SPECIAL REDUCING COUPLING
1
2
3
4
5
6
7
8

FIG. 5,386.—Roberts-Hamilton "thermo-seal" vapor vacuum heating system.

automatically goes to the vacuum side of the regulator and maintains the vacuum heat until more fuel is required or further regulation necessary.

Fig. 5,387 shows a thermostatic control or damper regulator which depends upon temperature changes for its operation.

Since the temperature of steam increases with the pressure evidently the expansion and contraction of a rod exposed to the steam can be made to operate the damper.

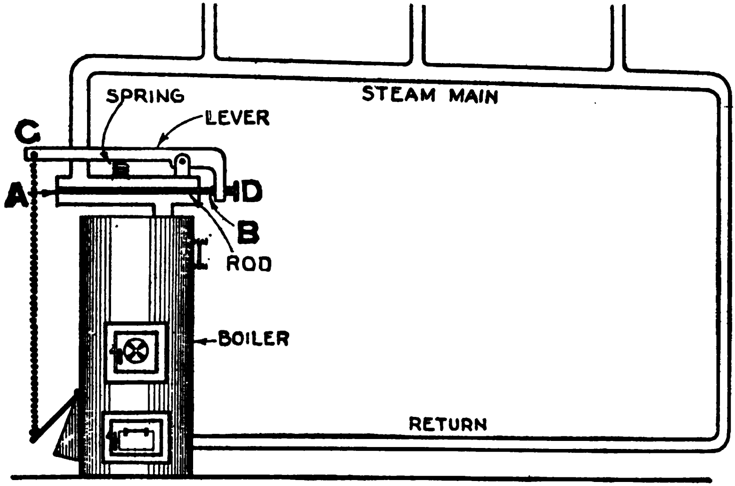


FIG. 5,387.—Thermostatic pressure control or damper regulator operating on changes in temperature of the steam coming from the boiler. The temperature of saturated steam in contact with water depends upon the pressure under which it is generated. At the ordinary atmospheric pressure (14.7 lbs. per sq. in.) its temperature is 212° F. As the pressure of the steam is increased or decreased, its temperature is increased or decreased respectively, thus for a 9.7-in. vacuum the temperature is 193°; for a 22 in. vacuum, only 153°.

In the figure such a rod is fastened at A, in a closed cylindrical chamber through which steam from the boiler passes to the main. The end B, is free to move, passing out of the chamber through a stuffing box. The motion of the rod is considerably magnified by the bell crank lever, which is connected to the damper by a chain attached at C.

In operation as the pressure of the steam rises its temperature will increase and the rod, which is made of a metal having a higher coefficient of expansion than that of the cylindrical chamber, the end B, will move to the right, thus causing end C, of the lever to descend closing the damper.

When the pressure falls, the rod contracts, and the spring which keeps the bell end in contact with the rod causes end C, of the lever to rise and open the damper.

The lever will assume some intermediate position then holding the steam at some predetermined pressure, which may be varied by means of the screw adjustment D. In this arrangement, there is no provision for securing excess pressure to purge the system of air at starting—this must be done by hand control of the damper.

A more extended control depends on both pressure and temperature for its operation. Fig. 5,388 shows an arrangement of this kind.

The regulator employs pressure for starting and temperature for running. In starting, the thermostatic portion of the regulator is closed off from the system, and it is necessary to produce enough pressure (less than one pound) to force the air from the system. When this is accomplished, the regulator automatically opens a valve to the thermostatic portion, which then maintains the temperature desired, its range embracing both vacuum and low pressure operation.

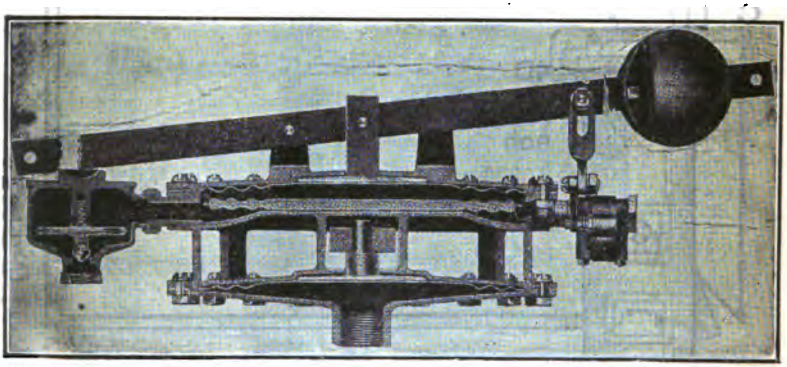


FIG. 5,388.—Roberts-Hamilton pressure-temperature damper regulator. The lower part is the pressure chamber and the upper, the thermostatic chamber. The thermostatic portion of the regulator is connected to the steam main and not to the boiler, so as to regulate the temperature in the radiators and mains. The volatile liquid contained in the double disc of the thermostatic portion is very sensitive and expands and contracts with the slightest change in temperature, so that if it be necessary to increase the temperature within the system, the slight contraction of the discs opens the dampers just enough to produce this temperature and then automatically closes them again.

Mechanical Vacuum Systems.—The term *mechanical* is here used to indicate vacuum systems in which an ejector or pump is used to maintain the vacuum, as distinguished from the *natural* vacuum systems already described.

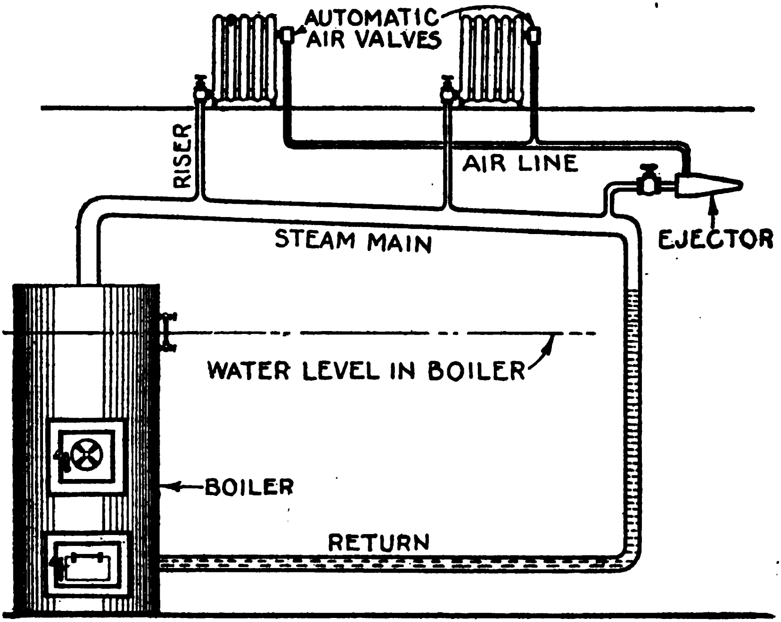


FIG. 5,389.—Ejector mechanical vacuum system as applied to one-pipe distribution. The thermostatic air valves are piped to the air line which has an ejector for ejecting air from the system. The ejector may be operated by live steam or water under pressure. A test made at the Ohio State University showed that 432 lbs. of steam was required for the ejector per 8,160 lbs. of condensation, or approximately 5%. Of course, this steam need not be wasted as it could be utilized in various ways, as, for instance, passing it through a radiator for heating.

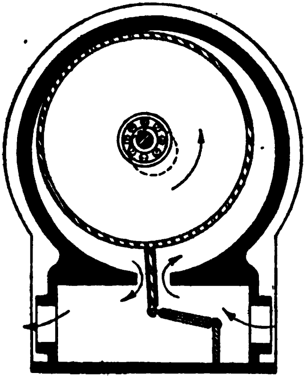


Fig. 5,389 shows an ejector system in which the ejector removes the air only, the condensation returning to boiler by gravity.

FIG. 5,390.—Thompson air line vacuum pump; sectional view showing construction and method of operation. It operates with a rolling motion, but the impeller does not revolve and does not require a water or oil seal.

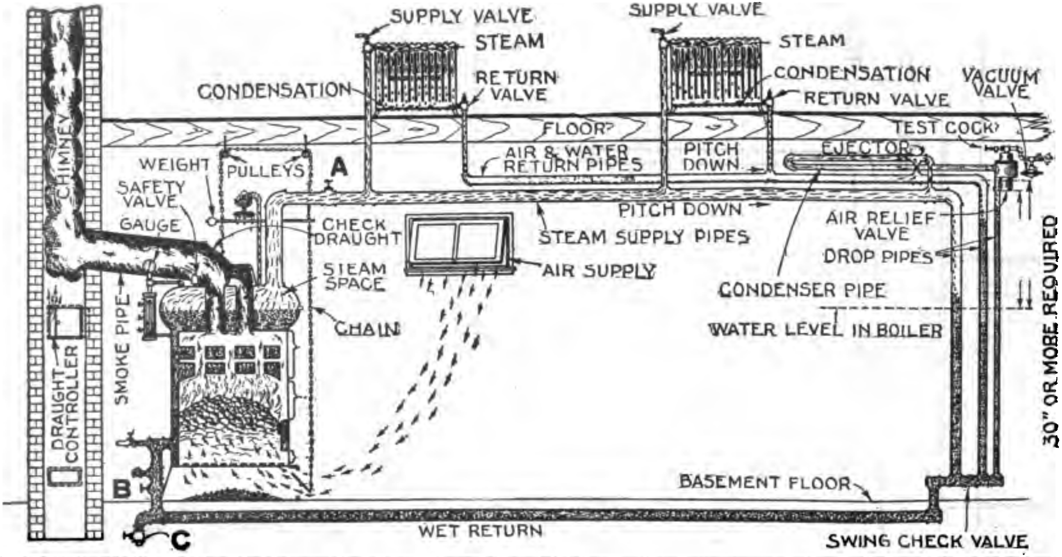


FIG. 5,391.—Sectional view showing construction and operation of Moline mechanical vacuum system. ***In operation,*** the heat expands the air in the boiler and pipes, driving it through the *ejector* at a speed which creates a slight suction on the return pipes. This suction pulls the air out of the return pipes and radiators and through the ejector. The air passes from the ejector into the *condenser* and from there out into the atmosphere, through an air relief valve. Before all the air is discharged, the water boils and a vapor is generated. This vapor is at first under a few ounces of pressure, and follows the easiest course, filling the supply pipes and radiators before it reaches the return pipes. When all of the radiators are fully heated, the surplus vapor enters the return pipes and passes through the ejector into the small condenser pipe. The condenser pipe acts as a chamber for collecting the mixed air and vapor and protects the air relief equipment. The air valve automatically closes after the air is expelled, being actuated by the heat of the vapor. **As the steam condenses a vacuum is formed, the radiators giving off a mild heat.**

This system is applicable to either the one pipe or two pipe systems, the figure showing the one pipe arrangement. Thermostatic air valves are placed on each radiator as shown. These air valves being connected by a pipe called the "air line" to the ejector.

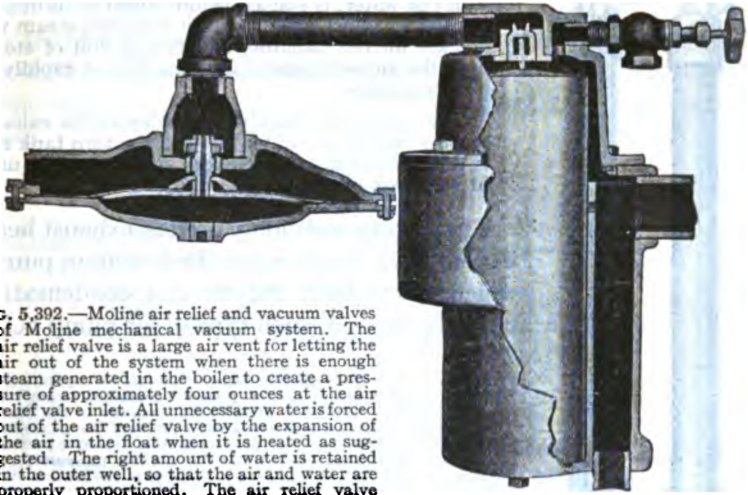
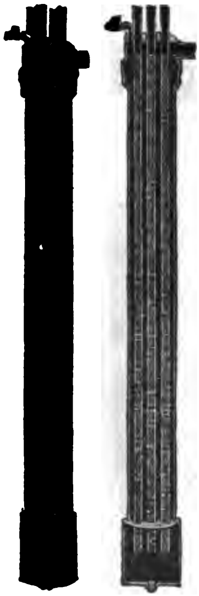


FIG. 5,392.—Moline air relief and vacuum valves of Moline mechanical vacuum system. The air relief valve is a large air vent for letting the air out of the system when there is enough steam generated in the boiler to create a pressure of approximately four ounces at the air relief valve inlet. All unnecessary water is forced out of the air relief valve by the expansion of the air in the float when it is heated as suggested. The right amount of water is retained in the outer well, so that the air and water are properly proportioned. The air relief valve will open when it cools by the air in the float contracting and drawing the water from the well surrounding the float into the float itself, which naturally makes the float heavy and causes it to drop, and the air relief valve is then ready to release the air from the system, when the pressure is again generated in the boiler. When the boiler draughts are opened and steam is again generated fast enough to displace the air in the heating plant, the air will pass out through the air relief equipment automatically until the steam reaches the air relief valve and expands the air in the float; then the float will again rise and close the valve, preventing the steam escaping. The vacuum valve is used on all work where the steam supply fluctuates. It is used for the purpose of keeping the air from re-entering the system when the steam pressure is permitted to drop below zero, or what is called atmospheric pressure, on gauge. When the steam condenses in the radiators faster than it is being produced at the boiler, a vacuum condition takes place, which lowers the pressure inside of the radiators and pipes to less than atmospheric pressure on the outside. Then the air would get back into the system, through the air relief valve, if it were not for the vacuum valve. This vacuum valve is used on heating plants where the pressure fluctuates: as where the heat is regulated by the boiler draught,or where it is not possible to employ a janitor to keep a steady pressure and give constant attention to the heating plant, such as residences or other small or medium sized buildings where individual boilers are used. On large plants, where high pressure is carried on boilers continuously and this pressure is reduced by means of pressure reducing valves; or in connection with central station heating plants, or exhaust steam plants, where a constant supply of steam is always available, there is no need of using the vacuum valve because the production of the steam is always greater than the condensation in the radiators, if the plant be properly designed and installed. In such cases a screen is used at the outlet of the air relief valve instead of the vacuum valve as shown in the illustration above. The vacuum valve operates on the differential principle, using the pressure on the area of a very large diaphragm, to close a valve having a much smaller area. The large diaphragm drops of its own weight, holding the valve open, under normal conditions, or when the pressure in the system, is lower than the atmosphere. The space below the diaphragm is open to the atmosphere. When the steam in the radiators condenses, thereby lowering the pressure in the system or in other words, creating a vacuum, the higher atmospheric pressure is exerted on the lower side of the diaphragm, closing the valve seat. The more vacuum created, the tighter this valve closes.



The ejector, which may be operated either by steam or water, is started before steam is turned on the system, thus, after the air is removed, steam will quickly fill the radiators and remain full of steam since the air is automatically removed as rapidly as it accumulates.

The system is equally well adapted to exhaust heating, where the water flows to a return tank and is pumped back to the boilers, and is largely used in this class of work.

The system commonly used in exhaust heating employs an *air* or so called vacuum pump, which ejects both the air and condensation from the system, such type of air pump being

Figs. 5,393 and 5,394.—Moline anti-syphon seal for separating the water from the steam or low pressure combined steam traps. These seals will hold back about 3 lbs. pressure in the lines to be drained. They prevent any greater pressure being carried on these lines, and in this way provide against excessive pressures, while giving a range three times the working pressure for the heating mains. The seals are set at the ends of the heating mains. As condensation occurs it flows through the seals. The outlet of the seal is piped to the point of disposal of the condensation, or the receiver of a return trap, steam pump, etc., as conditions demand.

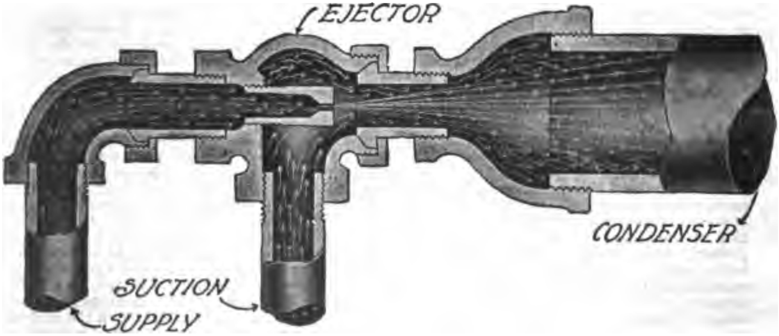


Fig. 5,395.—Moline ejector of Moline mechanical vacuum system. This ejector in connection with a condenser at the end of each main provides for the removal of air from the mains without any dependence on automatic parts.

called a *wet* air pump, as distinguished from a *dry* air pump, which handles only air.

A feed pump is used to return the condensation to the boiler. Fig. 5,396 shows the essential features of the system as applied to the fractional valve distribution. This gives a natural circulation.

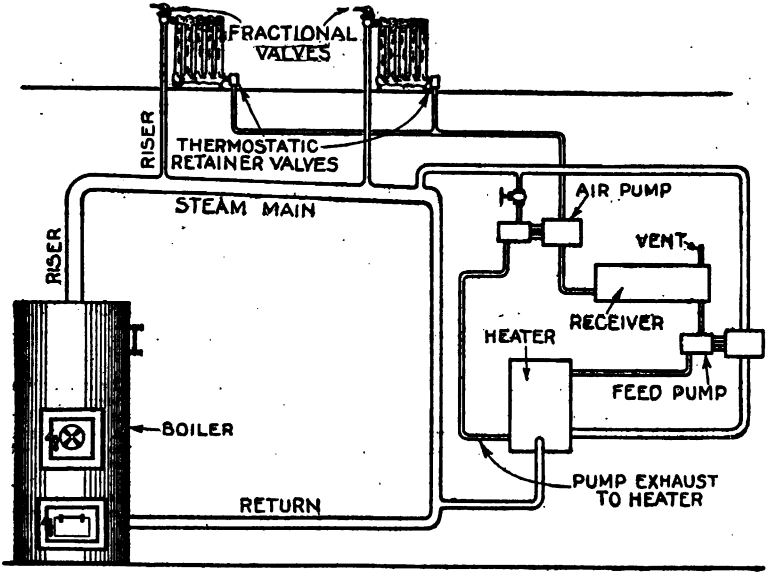


FIG. 5,396.—Air pump mechanical vacuum system as applied to fractional valve distribution. Air pumps are commonly used for maintaining a vacuum on exhaust steam heating systems. The air pump mechanical vacuum system consists essentially of: 1, *thermostatic retainer valves* at the radiators (to prevent steam reaching air pump and breaking vaccum); 2, *receiver* (for discharge from air pump, and having a vent to allow air to pass off); 3, *feed pump*, to pump condensation back through 4, *heater*, to boiler.

In operation, air, being heavier than steam, passes off through thermostatic retainer valves to the air pump. When the steam reaches these valves they close automatically to prevent the steam passing into the return line to air pump and breaking vacuum.

The discharge from the air pump passes into a receiver where the air is allowed to escape through a vent.

The condensation is pumped from the receiver back into the boiler by the feed pump, passing on its way to the boiler, through a heater, where it is heated by the exhaust steam from the air and feed pumps.

Exhaust Steam Heating.—The term exhaust steam heating relates to the *source* of the steam rather than to its distribution. In fact, after the exhaust steam enters the heating system its action is no different from live steam taken from a heating boiler, it being adapted to both low pressure and vacuum systems. The chief differences are the provision for delivering the steam from the engine to the heating system free from oil and at constant pressure, and for returning the condensation to the boiler at high pressure.

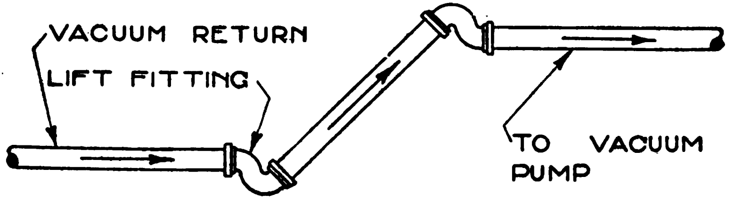


FIG. 5,397.—Lift fittings. The arrangement here shown is adapted for use on the main return lines of vacuum heating systems at points where it is desired to raise the condensation to a higher level. *In operation,* the momentum of the water is maintained and assists in making the lift with a minimum loss of vacuum. The lift fitting is constructed with a pocket at the bottom of the lift into which the water drains. As soon as sufficient water accumulates to seal this pocket it is drawn to the upper portion of the return by the vacuum produced by the pump. The shape of the fitting is such that dirt and scale are usually swept along by the current. Clean out plugs are, however, provided for use, if necessary. A second fitting in a reversed position is recommended for use at the top of the lift (as illustrated) to prevent water running back while the pocket is filling.

Fig. 5,399 shows the essential features of an exhaust heating system, with fractional control vacuum distribution. The

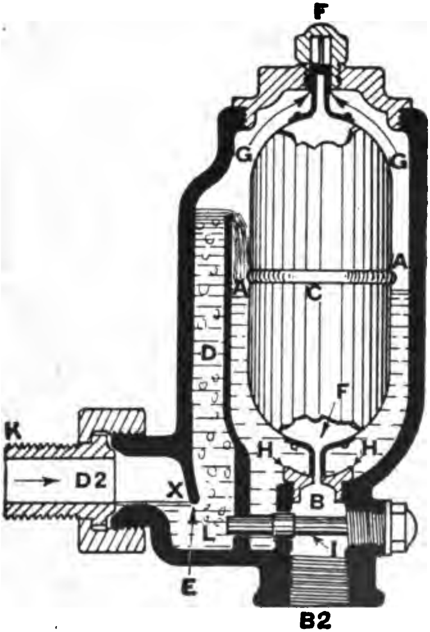


FIG. 5,398.—Sectional view of Van Auken vacuum retainer valve. ***In operation,*** the water of condensation is drawn through passage D and accumulates in pocket L, until it reaches the inverted weir E, it is then drawn upward in space D, until it overflows into the float chamber AA, here it accumulates until the line of floatation is reached. This causes the float C, to lift, opening the valve seat at HH, which allows the water to escape into the vacuum return pipe B2. After the removal of the water the float again settles on seat HH, until sufficient water accumulates in float chamber AA, to again lift the float. The air contained in the radiators or coils, due to condensation, enters through passage FF, and is drawn through the column of water in space D, into the top of float chamber AA. Here its direction follows arrows GG, being drawn through the small opening in guide-pin at F, down through the hollow body of copper float, past the valve seat at HH, into the vacuum return B2. This removal of air is continuous regardless of the amount of water present. The by pass I, when opened allows all dirt, core sand or scale to pass directly into the vacuum return thus cleaning the valve and preventing clogging by any foreign substance; the arrangement of by pass is such that the water may be emptied from chamber AA, without interfering with conditions existing in space D. There is no possibility of steam escaping into the vacuum return as the column of water in space D, acts as a water seal, which even in the smallest retainer valve, is three inches deep; also the opening on top of guide at F, is so constructed that steam cannot enter. The pin upon which this travels insures an opening free from foreign matter at all times. The upper and lower guide valve pin are interchangeable, making it immaterial as to how the float is placed in the valve as it works successfully either way. The pin or guide projecting from the cap on top of the valve, keeping the float in proper position. The air outlet being free at all times and the accumulation of foreign matter in the air passage is therefore impossible.

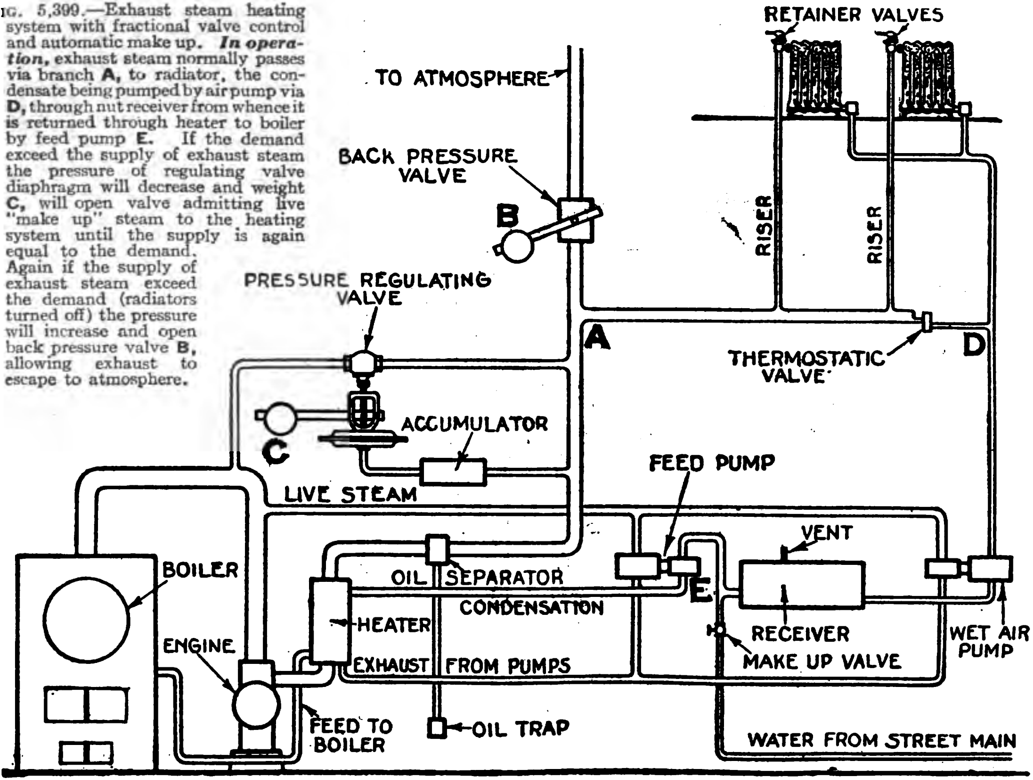


FIG. 5,399.—Exhaust steam heating system with fractional valve control and automatic make up. *In operation,* exhaust steam normally passes via branch **A**, to radiator, the condensate being pumped by air pump via **D**, through nut receiver from whence it is returned through heater to boiler by feed pump **E**. If the demand exceed the supply of exhaust steam the pressure of regulating valve diaphragm will decrease and weight **C**, will open valve admitting live "make up" steam to the heating system until the supply is again equal to the demand. Again if the supply of exhaust steam exceed the demand (radiators turned off) the pressure will increase and open back pressure valve **B**, allowing exhaust to escape to atmosphere.

necessary devices between the engine and inlet to heating system are:

1. Oil separator and trap,
2. Back pressure valve,
3. Pressure regulating valve,

and for mechanically producing the vacuum and reducing the condensation to the high pressure power boiler,

1. Air, or so called vacuum pump,
2. Receiver with vent,

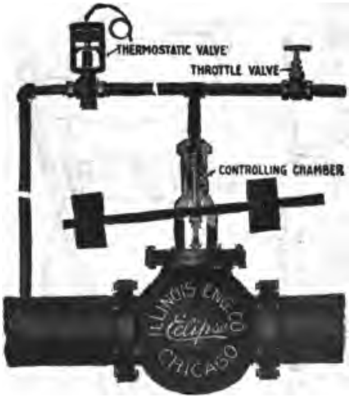


FIG. 5,400.—Illinois "Eclipse" combination temperature regulator. This valve is used to control the temperature of steam, gas, air or water by temperature. It can be arranged to shut off or open as desired with a slight variation of the temperature existing at some desired point.

3. Feed pump,

in addition a feed water heater is provided both for economy and to permit returning condensation and make up feed water to boiler at the proper temperature.

In operation exhaust steam from the engine first passes through the heater, then through the oil separator, which frees it from the lubricating oil, the latter passing off into the oil trap. The steam now enters the heating system at A, its pressure being prevented rising above a predetermined limit by the back pressure valve (regulated by weight B), and maintained

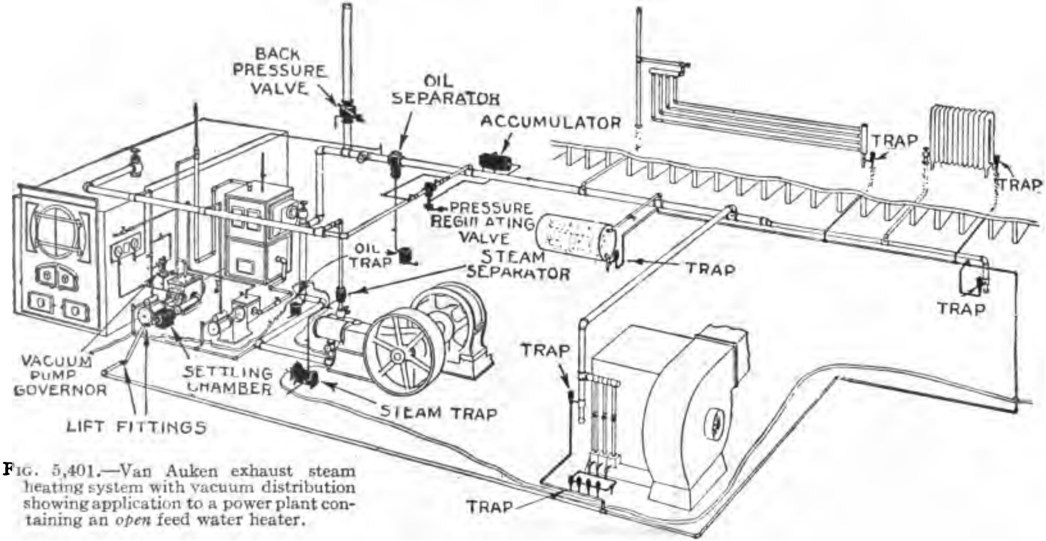


FIG. 5,401.—Van Auken exhaust steam heating system with vacuum distribution showing application to a power plant containing an *open* feed water heater.

at a predetermined constant pressure by the pressure regulating valve (adjusted by weight C). This is in fact an automatic steam "make up" valve which admits live steam to the heating system when the exhaust is not adequate to supply the demand, thus "making up" for this deficiency and maintaining the pressure constant.

The fractional control vacuum system is shown but any other system may be used to suit the conditions.

Condensation and *air* is removed from the heating system at D, by a *wet* air pump (as distinguished from the *dry* type which removes air only). The condensation and air is discharged into a receiver where the air passes off through a vent, the condensation being pumped by a feed pump back into the boiler after passing through a feed water heater.

Since there is a continual loss of water through various leaks, the feed pump suction is connected at E, with the supply from the street main or other source, the amount entering the system being controlled by the "make up" valve

The various automatic devices, such as back pressure valve, pressure regulating valve, etc., necessary to adapt the exhaust to heating purposes, are shown in the accompanying illustrations.

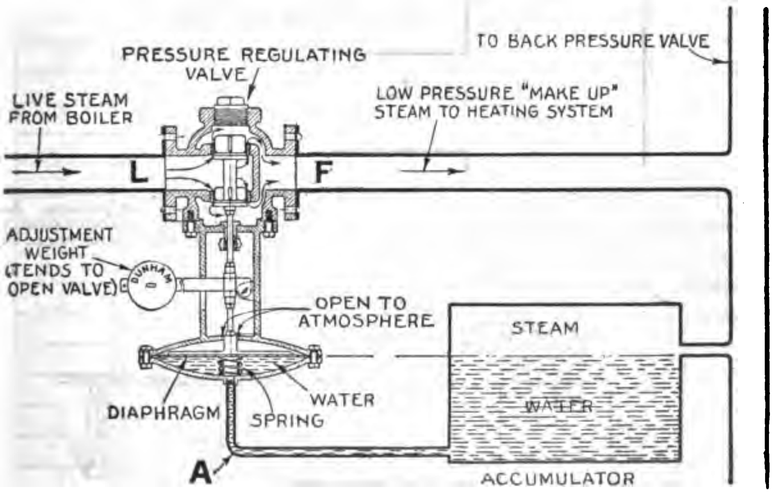


Fig. 5,402.—Pressure regulating valve and accumulator for maintaining a constant pressure in the steam heating main. It maintains the pressure constant by automatically admitting steam when the supply from the exhaust is not adequate to meet the demand, the amount of steam thus admitted being that necessary to prevent fall of pressure. The valve is controlled by means of a governing pipe A, connecting the diaphragm chamber to the accumulater, the latter being connected to the heating main at the point from which the pressure regulator is to be governed. The accumulater is always half full of water and its elevation must be such that the water line in the accumulater is level with the diaphragm, so that there will not be an unbalanced column of water to exert pressure on the diaphragm. The water protects the diaphragm from the steam, the pressure of the latter being transmitted from the surface of the water in the accumulater to the diaphragm. ***In operation,*** when the exhaust side F, is at the predetermined pressure, this brings sufficient force against the under or water side of the diaphragm to overcome the downward thrust due to the adjustment weight and close the valve. Now if the engine slow down, or there be a heavy demand for heat so that the exhaust is not adequate, the pressure in the exhaust side F, will fall, and the downward thrust of the adjustment weight will overcome the opposing pressure of the water on the diaphragm and open the valve admitting live steam from the boiler side L, into the exhaust side F, in sufficient quantity to restore the pressure. The inertia of the water in the accumulator acts as a damper to prevent oversensitiveness of the valve, or "*hunting,*" due to slight momentary fluctuations of pressure in the exhaust side F. The spring under the diaphragm is to balance the downward thrust of the lever and hold the valve in closed position when the pressure is the same on both sides of the diaphragm.

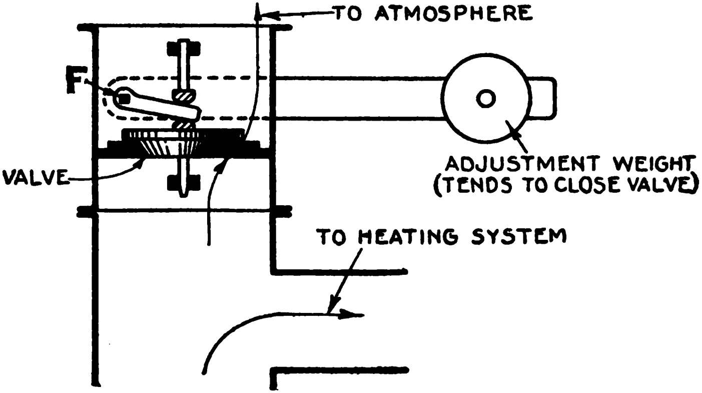


FIG. 5,403.—**Back pressure valve to prevent exhaust pressure exceeding a predetermined limit. This is virtually a lever safety valve designed to work at very low pressure. *In construction,* some back pressure valves are so sensitive that they will open or close with a variation of only 2 ounces. The position of the weight on the lever which is fulcrumed at F, determines the exhaust pressure at which the valve will open.**

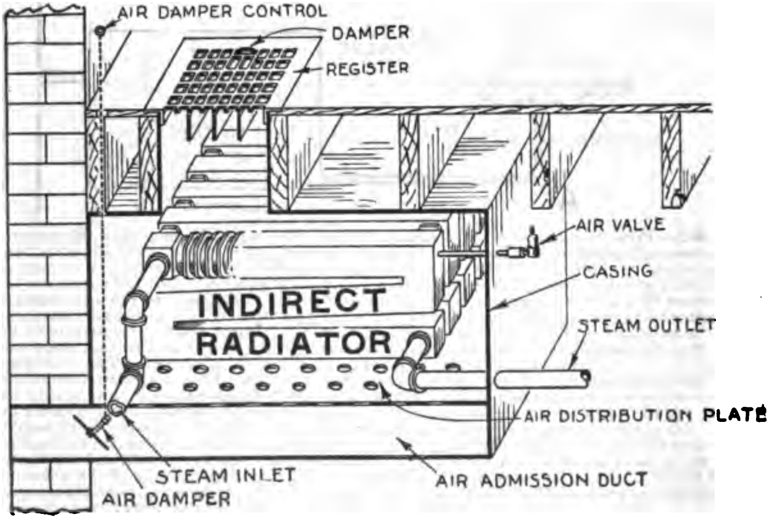


FIG. 5,404.—***Indirect* heating showing indirect radiator, its placement in air tight casing with duct from outside, distribution plate damper control, and connection with hot air register. The advantage of indirect heating is thorough ventilation, but it is more expensive than direct heating both in installation and in operation.**

INDIRECT HEATING

This is a combination of steam or hot water heating and hot air heating, the object of the system being to secure the advantage of steam or hot water as a heating medium and avoid the disadvantages of these or of the hot air furnace.

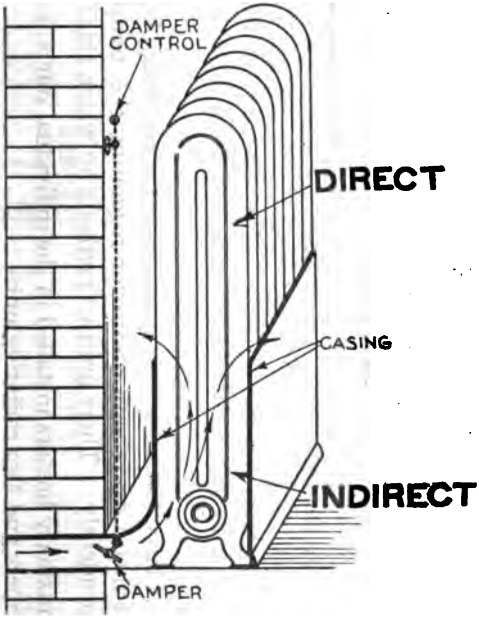


FIG. 5,405.—***Indirect-direct*** **heating showing encasement of radiator and air duct connecting with the outside. An air damper regulates the amount of air entering.**

Indirect heating secures thorough ventilation because, in principle, fresh air from the outside is passed over a radiator placed in an air duct or flue, the heat imparted to the air causing a brisk circulation, thus fresh air is constantly entering the room to be heated, instead of reheating the same air as in direct heating.

In the purely indirect system, the radiating surface (ill advisedly called "heating stack") is placed somewhere remote from the room to be heated, as in fig. 5,404, as distinguished from the *indirect-direct* system in which the radiator is placed within the room to be heated but its lower half is so encased and connected to the outside of the building that fresh air is continually drawn into the room as in fig. 5,405.

Forced Indirect, or Hot Blast Heating.—As generally

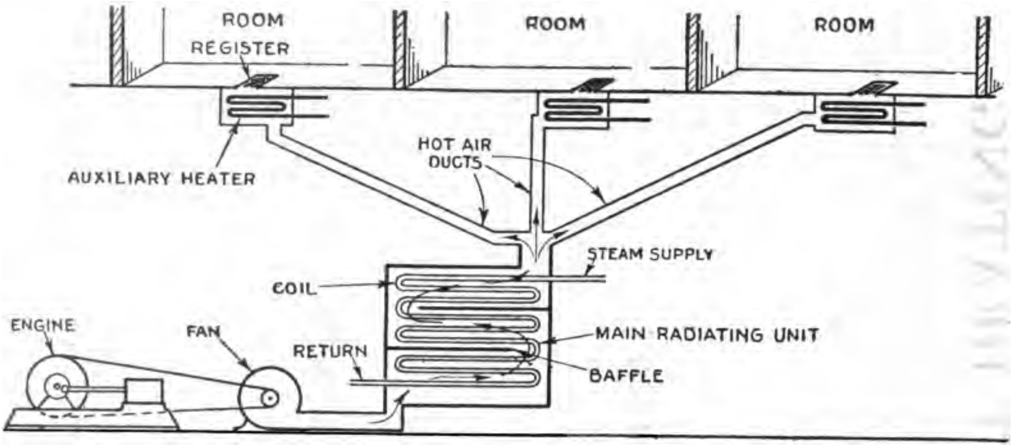


FIG. 5,406.—Hot blast indirect heating with a main radiating unit and individual supplementary heaters.

understood the term hot blast heating refers to indirect heating in which a fan is used to force the air over the radiating surface as distinguished from the natural air circulation just described.

There is usually one large radiating unit from which hot air is supplied to the different rooms through sheet metal ducts with means for regulating the temperature of the air supply to each independently. There are two methods by which this is done.

1. By the use of auxiliary heaters installed in the individual ducts, or,
2. By mixing dampers and two radiating units.

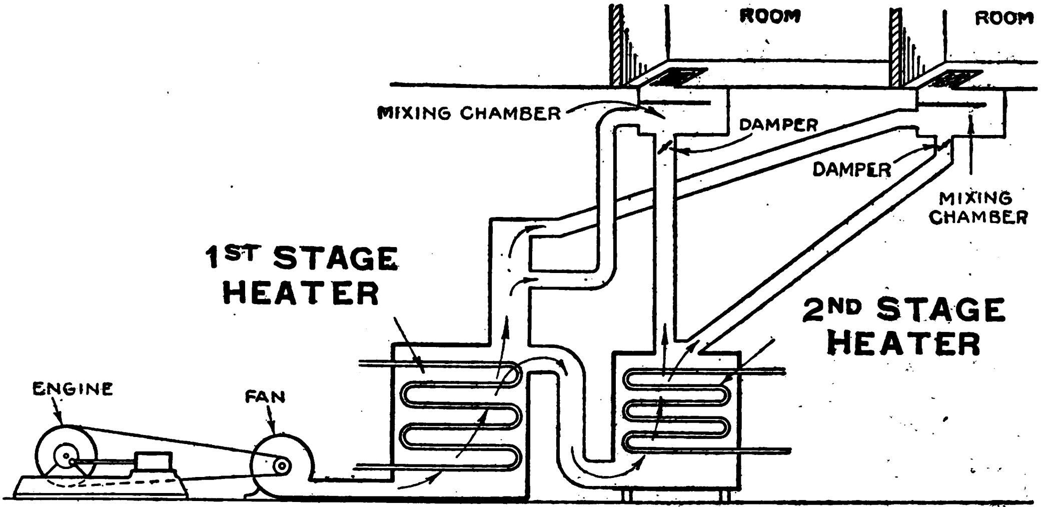


FIG. 5,407.—Hot blast indirect heating with first and second stage main radiating units.

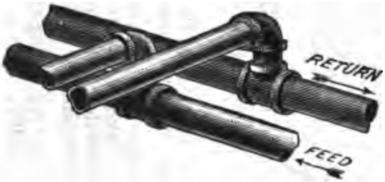
In the first arrangement the air is heated to a temperature of about 70 degrees F. by the main radiating unit and then as much higher as desired by the auxiliary heater, as shown in fig. 5,406.

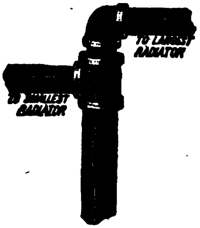
In the second method, two heaters are provided, one large enough to raise the temperature of the entire air supply to 68 or 70 degrees, and the second arranged to take from $1/3$ to $2/5$ of the tempered air and raise its temperature as much higher as may be desired. Two ducts are run from the main radiating units to the bases of the uptake ducts, one carrying tempered air, and the other hot air.

A mixing damper is provided at the base of each duct for regulating the temperature of the air to give the required temperature in the rooms, as shown in fig. 5,407.

2 HOT WATER HEATING

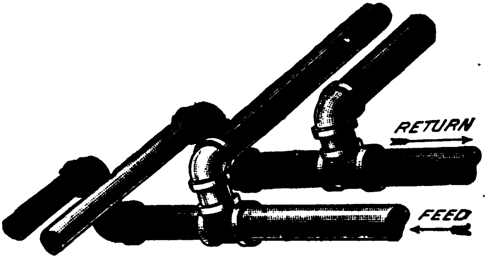
Water, as a medium for transmitting heat in heating dwellings possesses several advantages over steam:





FIGS. 5,408.—Best method of taking connection from the top of main flow and return in hot water heating. A 45° elbow may be taken from the top if the head room be limited. Steam connections should be taken off the main in the same way.

FIG. 5,409.—Proper method of taking off connections from a hot water riser on the same floor, one being larger than the other.



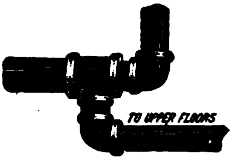


FIG. 5,410.—Best method of taking hot water connections from the end of mains. The end connections should turn up and the pipes run at the same level as the pipes nearer the heater so as to give the last pipes the same advantage as the others.

FIG. 5,411.—How connections on hot water risers should be made so as to give all the advantage to the lower floor. The tendency is for the hot water to flow to the upper floors and means similar to the above are necessary to offset this tendency.

NOTE.—The author is indebted to Giblin & Co. for the above illustrated piping suggestions for hot water heating.

1. Because of the low working temperatures the heat is very mild and the atmosphere is not robbed of any of its healthful qualities.

2. Since the temperature may be varied it is more flexible than low pressure steam systems.

3. The radiators will remain warm a considerable time after the fire is extinguished, thus the system is a reservoir for storing heat.

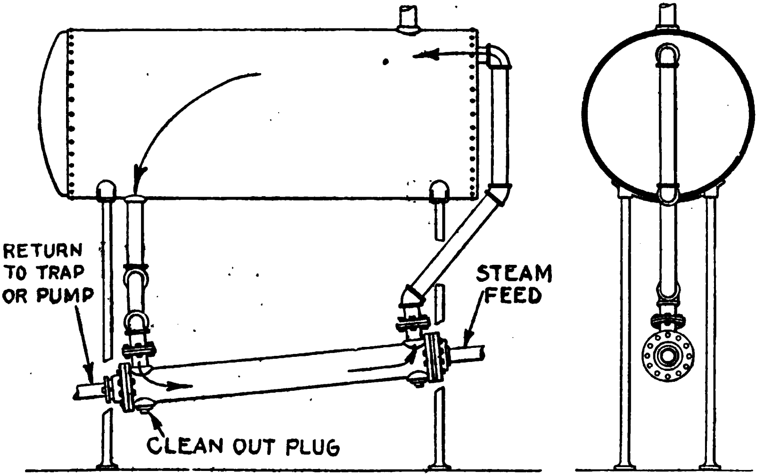


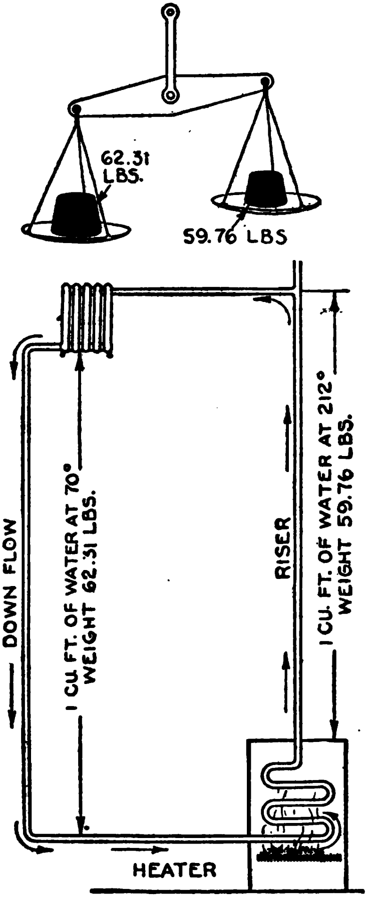
Fig. 5,412.—**Water heater set up in connection with a storage tank. It can be used in this way for exhaust or high pressure steam, and the water of condensation may be returned to a well by a trap, or taken to a pump governor, provided the pump receiver do not carry pressure. The water of condensation should drain freely from the tubes to get good results.**

As with steam heat, there are numerous hot water heating systems. These may be classed

1. With respect to circulation, as

a. Natural

b. Accelerated {
By excess pressure
" superheating
" steam or air
" pumps


62.31 LBS.
59.76 LBS
DOWN FLOW
1 CU. FT. OF WATER AT 70° WEIGHT 62.31 LBS.
RISER
1 CU. FT. OF WATER AT 212° WEIGHT 59.76 LBS.
HEATER

Figs. 5,413 and 5,414.—Motive force in natural circulation hot water heating system. The question is often asked, "Why does the water circulate?" It is due to the difference in density of water at different temperatures. Thus in fig. 5,414, if the riser pipe hold say 1 cu. ft. of water at 212° its weight is 59.76 lbs., and similarly if the return pipe hold 1 cu. ft. of water at 70° its weight is 62.31 lbs. Thus the column of water in the return pipe is 62.31—59.76 = 2.55 lbs. heavier than the column of water in the riser. This unbalanced weight forms a motive force which causes the water to circulate through the system as indicated by the arrows, and further portrayed by the effect of the unequal weights placed on the beam scale, fig. 5,413.

2. With respect to the piping arrangement, as

a. Single pipe system.
b. Two pipe system.
c. Circuit system.
d. Overhead system.

3. With respect to the principle of air circulation, as

a. Direct.
b. Indirect.
c. Indirect direct.

4. With respect to pressure, as

a. Low pressure.
b. High pressure.

NATURAL CIRCULATION

In order that water may transmit heat from the heater to the radiators there must be a constant movement of the water from the heater to the radiators and back again, or *circulation* as it is called. In natural circulation systems, this circulation is due to the difference in density or weight of water at different temperatures.

Thus 1 cubic foot of water at 70 degrees F., weighs 62.31 lbs. and at 212 degrees, 59.76 lbs. representing a difference in weight of 62.31—59.76 = 2.55 lbs., which is available to cause circulation, as shown in fig. 5,413. The difference in weight is due to the *expansion* of water as its temperature is raised.

Fig. 5,415 shows the essential features of a two pipe low

The following table gives the relative volume of water at different temperatures compared with its volume at 39.1° Fahr., according to Kopp, as corrected by Porter.

Expansion of Water

Fahr.	Volume	Fahr.	Volume
39.1	1.00000	122	1.01186
41	1.00001	131	1.01423
50	1.00025	140	1.01678
59	1.00083	149	1.01951
68	1.00171	158	1.02241
77	1.00286	167	1.02548
86	1.00425	176	1.02872
95	1.00586	185	1.03213
104	1.00767	194	1.03570
113	1.00967	212	1.04332

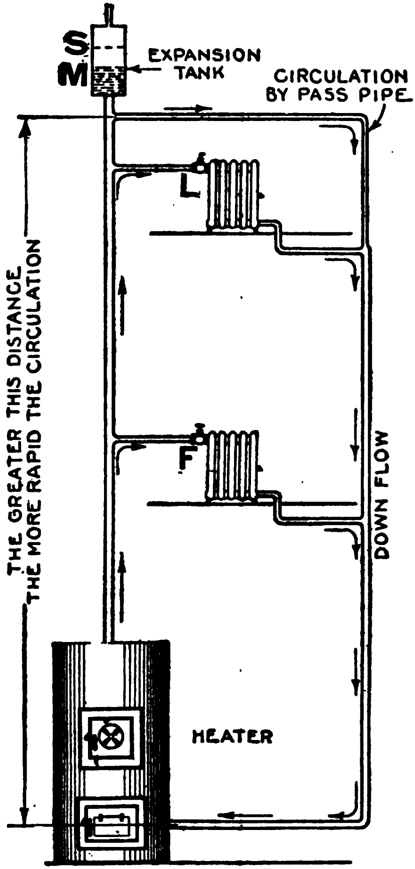


Fig. 5,415.—Two-pipe natural circulation hot water system. ***In operation,*** after the fire is started the temperature of the water in the heater rises, and expands; this disturbs the equilibrium of the system, causing the colder and heavier water in the down flow pipe to flow downward, pushing the warmer and lighter water in the riser upward, thus starting circulation, a circulation by pass pipe being provided to form a continuous path for the flowing water in case all the radiators be shut off. The expansion of the water will cause it to rise in the expansion tank from M to some higher level as S. Now if valves L and F, be opened the water will flow through the radiators, where most of its heat is absorbed in heating the rooms. This will increase the density of the water in the down flow pipe, thus accelerating the circulation. Air vents on the radiator are necessary. Because of this expansion it is necessary to leave the highest point of a hot water system open to the atmosphere and provide at that paint an expansion tank for the variation in volume,

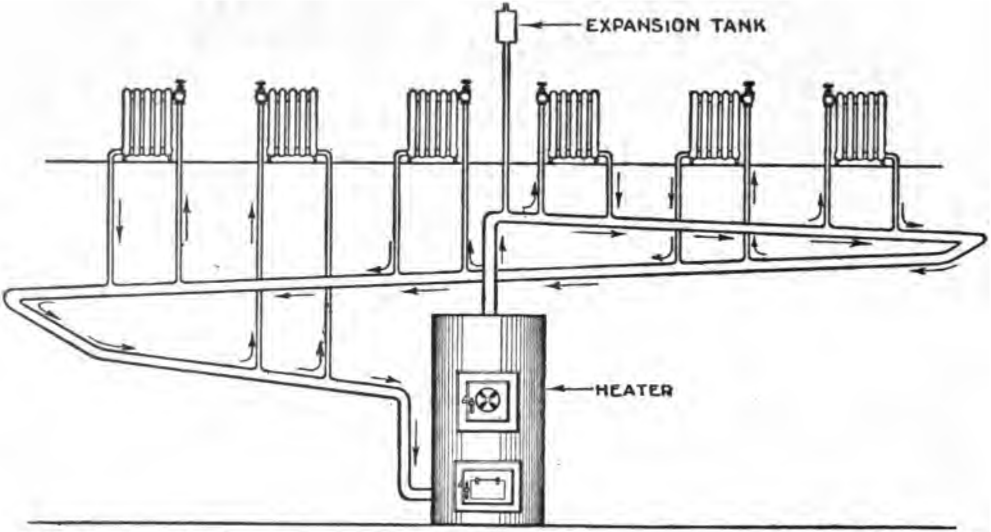
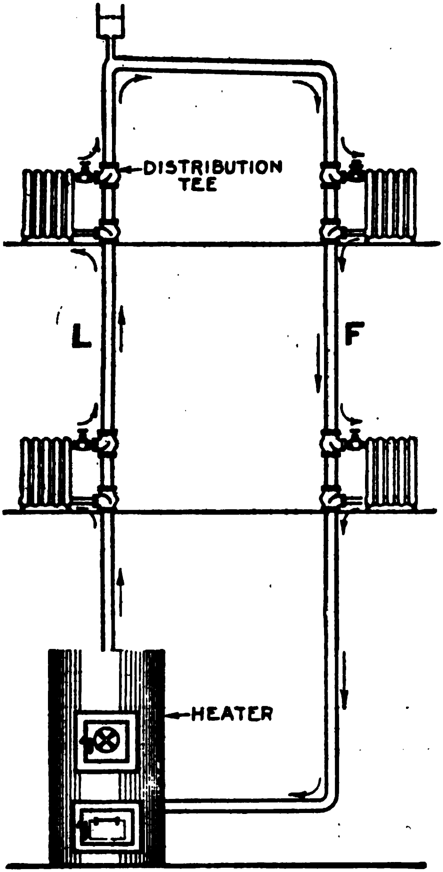


FIG. 5,416.—Circuit two pipe natural circulation hot water system. A single main pipe is taken to a high point under the basement ceiling and then pitched along its run as much as possible to the return inlet of the heater. The risers are taken off the top of the main and the down flow pipes are tapped at the side with tangent tees. Where the riser and return are very close together a special fitting is used, so arranged that the flow to radiators leaves the top of the main and the return or down flow enter at the bottom. Air vents on the radiators are necessary.

pressure system, this being shown first as it is more easily understood than the so-called one-pipe system.

The circuit system is shown in fig. 5,416. The circuit consists of a closed loop of extra large pipe in the basement, having a pitch not less than ½ inch per 10 feet of run. This main supplies all the risers to the radiators above.

The circulation in this arrangement is not so good as in that of fig. 5 415, and for this reason the circuit main should be of very liberal size to reduce friction to a minimum.



The so-called one-pipe system is shown in fig. 5,417. In this arrangement special distribution tees are employed to deflect part of the water from the main into the radiators while letting the balance flow through the main to the next radiator.

This is a single pipe system in the sense that one pipe serves both inlet and outlet of each radiator, but there must be an upflow side L, and a down flow side F, thus there are two main pipes.

Evidently the heat distribution by this method, as well as by the circuit system, fig. 5,416, is not uniform, the radiators on the upflow side L, being hotter than those on the downflow side F.

FIG. 5,417.—So called *one-pipe* natural circulation hot water system. L is the riser side and F the down flow side. The system consists of a vertical loop which carries both the supply and return water of the radiators. Special distribution tees having an internal baffle tongue facilitate the circulation to and from the radiators, this being shown in detail in fig. 5,418. No air vents on the radiators are necessary.

Fig. 5,418 shows the overhead system. This is virtually the same as the one-pipe system with the addition of a central riser to which no radiators are attached. Special distribution tees are used as in the one-pipe system of fig. 5,418.

High Pressure Hot Water Systems.—The heating systems thus far described are known as low pressure, being open to the atmosphere, although the head on some systems in big buildings makes them virtually high pressure systems. The object of increasing the pressure is to raise the boiling point, thus the water can be heated to a higher temperature when under high pressure without generating steam, than can be done with low pressure.

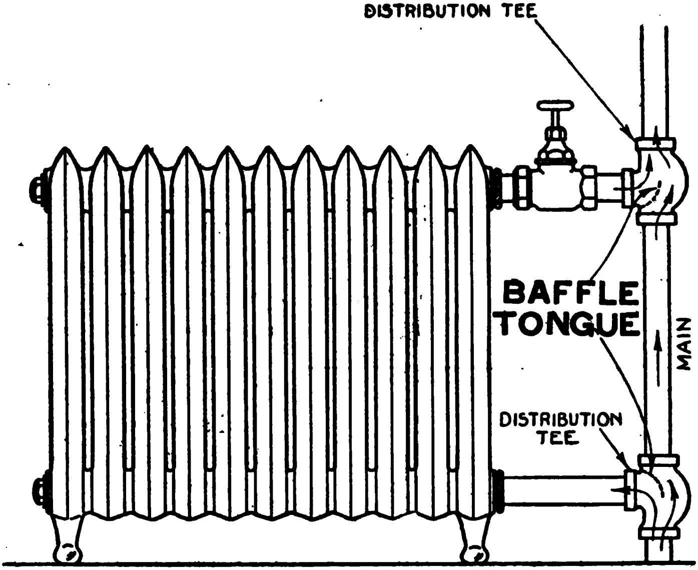
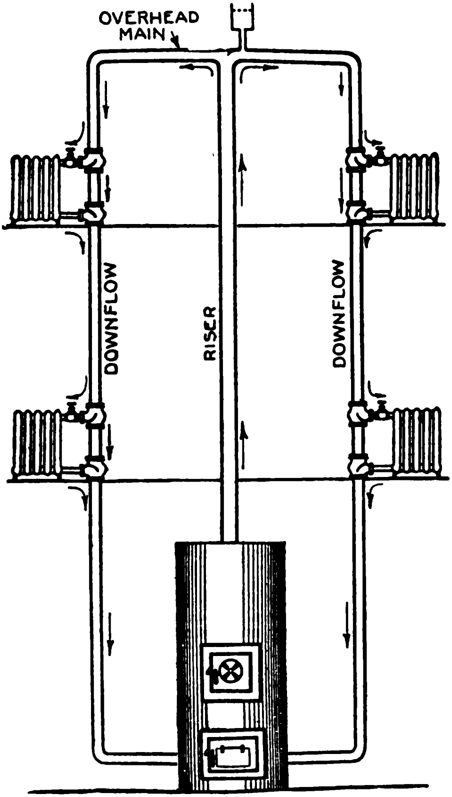


FIG. 5,418.—Distribution tees connecting radiator to main of so called one pipe system, shows baffle tongues which deflect part of the water from the main in and out of the radiator while by passing the balance along the main.

In England high pressure hot water systems are used for various purposes, such as laundry dryers, bake ovens, enameling, etc., the system working at from 250 to 350 degrees. The piping is relatively small, extra heavy pipe and fittings being used.

As distinguished from low pressure plants, high pressure systems are provided with closed expansion tanks, the tank containing water for the system, and air which forms a cushion. The expansion tank is provided with a safety valve.



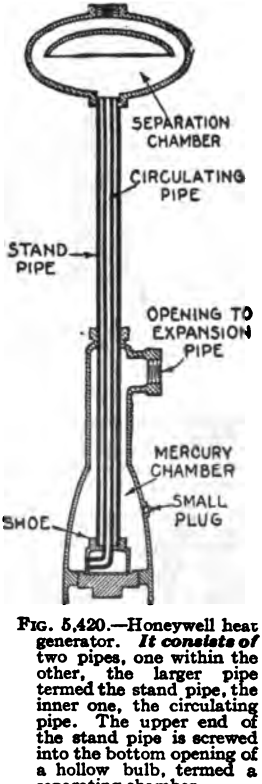
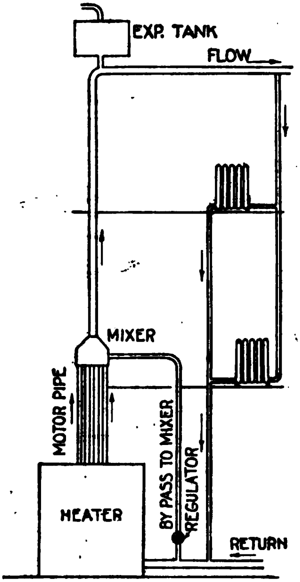


Fig. 5,420.—Honeywell heat generator. ***It consists of*** two pipes, one within the other, the larger pipe termed the stand pipe, the inner one, the circulating pipe. The upper end of the stand pipe is screwed into the bottom opening of a hollow bulb, termed a separating chamber.

Fig. 5,419.—Overhead system. It is considered by some as the best method of piping. Although it is not adapted to all classes of buildings, there are many, such as apartments, stores, office buildings, hotels, etc., where the general arrangement lends itself to this system. No air vents are necessary at any point on the system, as the arrangement is such that all air works to the top and passes off into the expansion tank.



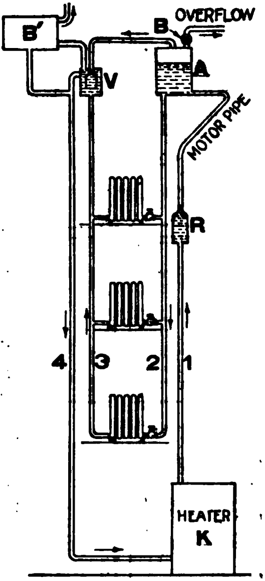


FIG. 5,421.—Koerting hot water heating system. *It has* a series of motor pipes leading from the upper part of the heater to a mixer, where the steam is condensed before it reaches the expansion tank by the water entering through the by pass from the return. The velocity of the steam and water through the motor pipes and the partial vacuum caused by the condensation in the mixer produces the acceleration up the flow pipe.

FIG. 5,422.—Jorgensen and Bruchner hot water heating system. The heater K, delivers the hot water up the flow pipe to a regulator R, where a separation takes place between the steam particles and the water, thus causing an acceleration up the motor pipe to the expansion tank A. The water in the flow pipe 2, is probably near to the temperature of that in 1. After passing through the radiators the water in 3, is at a lower temperature than that in 2. The steam particles which have collected in the expansion tank A, above the water line are condensed in V. The acceleration in the system is thus produced by a combination of the upward movement of the steam particles in motor pipe 1, and the induced upward current in 3, toward the condenser V.

FIG. 5,420.—*Text continued.*

chamber, which has also an opening at the top into which the pipe connection to the expansion tank is made. The lower half of the stand pipe is screwed into a bottle shaped hollow casting, terminating in a hollow cup or shoe screwed on the bottom of the pipe. The plug B, screwed into the bottom of the bottle makes it tight except for opening C, on one side near

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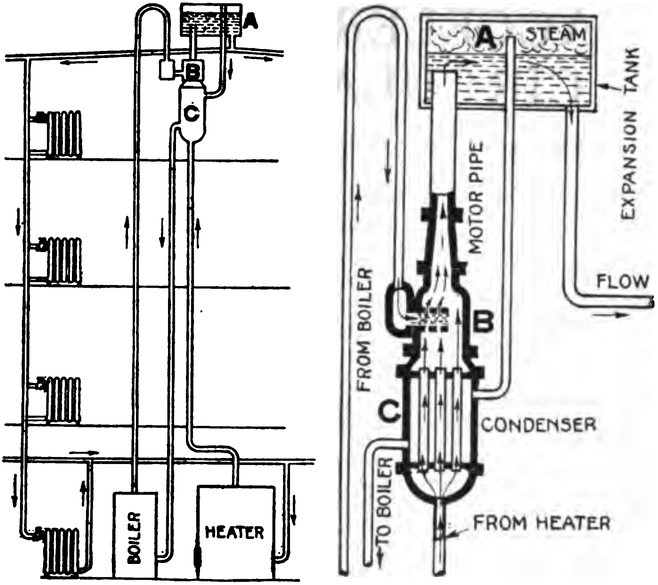
NOTE.—*It will be noticed* in figs. 5,421 and 5,422 that the condensation in one system takes place before the expansion tank and in the other system after it has passed the expansion tank. Each of the systems illustrated may be carried under pressure by a safety valve, or by an expansion tank located high enough to give sufficient static head.



FIGS. 5,423 and 5,424.—Reck system of hot water heating. *In operation*, the water passes directly from the heater up the main riser where it enters the condenser C, and thence into the expansion tank A, as a supply to the flow pipes of the system. Steam from a separate boiler is admitted to the mixer B, above the condenser and enters the circulating water just below the expansion tank. The velocity of the steam and the partial vacuum caused by the condensation induces a current up the flow pipe to the expansion tank. When the water level in the expansion tank reaches the top of the overflow pipe the water returns to the steam boiler through the condenser C, where it gives off heat to the upper current of the circulating water. It will be seen that the water in the system and the steam from the boiler unite from the inlet at the mixer to the expansion tank. On all other parts of the systems they are independent.

FIG. 5,421.—*Text continued*

the top of the casting, into which expansion pipe from heating system is connected. The lower part of the bottle is termed the mercury chamber, being filled with mercury to the height of the small plug D, making it approximately 1½ in. in depth. The principle of the operation of the generator is based on the fact that mercury is thirteen times heavier than water, and the apparatus is really a mercury seal, requiring a pressure of about ten pounds to break the seal and allow the pressure to reach the expansion tank. The various parts of the generator are so arranged as to allow the mercury to circulate under pressure and to be separated from the water by plate E, when the mercury seal is broken by excess of pressure on the system. As the mercury is heavier than the water, it settles again through space F, into the mercury chamber at the bottom of the generator. The rapidity of the circulation through small piping and reduced radiation, under a temperature equal to steam at ten pounds pressure, renders the reduced amount of radiation (10% reduction), effective for cold weather and the wide range of temperature allows of a mild degree of heat in warmer weather.

ACCELERATED CIRCULATION

By increasing the velocity of the circulation smaller pipes may be used, thus resulting in a reduction in cost of labor and material. Numerous devices have been introduced to accelerate the circulation and the following principles which have been employed may be mentioned.

1. High pressure to gain greater temperature difference.

2. Superheating a part or all of the circulating water as it passes through the heater and condensing the steam thus formed by mixing it with a portion of the cold circulating water of the down flow pipe.

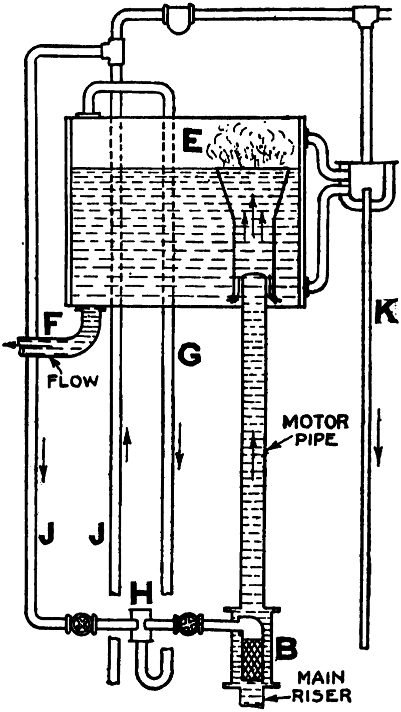


FIG. 5,425.—Modified Reck hot water heating system. *In this system* air is injected in the riser pipe at B, and causes the acceleration by a combination of the partial vacuum produced by the steam condensation as just mentioned and the upward current of the air particles as in an air lift. Steam enters through the pipe J, and ejector H, to the mixer at B, where it is condensed. In passing through H, air is drawn from the tank E, and enters the main riser with the steam. The upward movement of this air through the motor pipe to the tank induces an upward flow of the water in the main riser. By this combination there are formed three complete circuits, water, steam and air, uniting as one circuit from the mixer B, to the expansion tank E. The steam furnished may be supplied by a separate steam boiler or by steam coils in the fire box of a hot water boiler.

3. Introducing steam or air into the main riser pipe near the top of the system.

4. Forcing by pumps.

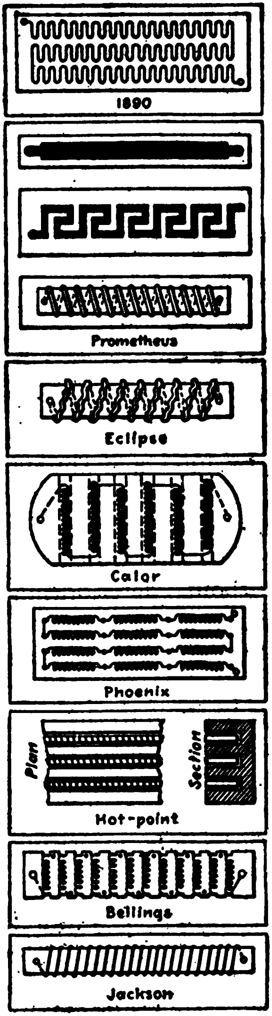
3

ELECTRIC HEATING

Production of the Heat.—For domestic and some industrial purposes, heat is produced by electricity by forcing it through resistance wires, raising the temperature of the latter, and applying the heat thus generated to the articles to be heated. Resistance wires are made of special materials and are capable of withstanding high temperatures without deteriorating. Metals and alloys having high specific resistance or low temperature coefficient of resistance are largely used for resistors.

Heating Units.—The term heating unit is given to that portion of a cooker or heater which gives out the heat for warming an oven or hot plate or for raising the temperature of a room. It consists of some material which is more or less a bad conductor of electricity, and when current is taken through it, by making it form a portion of an electrical circuit, it becomes hot owing to the resistance it sets up to the current. In order to meet the varied conditions of service there are numerous forms of resistor or heating unit, and these may be classified as:

1. Exposed coils of wire or ribbon open to air and wound around insulating material.



FIGS. 5,426 to 5,436.—Various types of heating unit.

2. Wire or ribbon in the form of coils or flat layers, embedded in enamel, asbestos, mica, or other insulators.

3. Filling of metal fixed on enamel, mica, or glass.

4. Metallic powder mixed with clay and compressed in forms, and crystallized silica in tubes of glass.

5. Incandescent filaments in vacuum.

Electric radiators for room heating consist usually of a resistance wire wound on asbestos tubes covered with a coating of fire proof cementing compound. When air is thus excluded, German silver may be used as a resistor.

The following details are given of some of the heating units in general use:

The Eclipse element consists of high resistance ribbon crimped to give greater length and free air space, wound over mica strips with the ends connected to heavy eyelet terminals.

The Calor element has a base of fire clay with grooves into which spirals of fine high resistance wire are placed.

The Phoenix element has spiral wire coils held lightly at short intervals by porcelain insulators mounted on a suitable base.

The Hot Point element is made up of nichrome wire or ribbon, wound lightly around thin strips of mica, then further covered with a thin mica covering and inserted very tightly into grooves or slots made in the hot plate or iron base to receive the finished strips.

The Belling element consists of a fire clay strip with spirals of nichrome wire stretched across the width of the base, notches being provided in the base for receiving the ends of the spiral and holding them tightly in position in the manner shown.

The Jackson element has a different class of fire clay base with quite a smooth surface, the section of the strips being a flat oval wire or ribbon of nichrome, is wound tightly over the strip in one continuous length and clamped between heavy terminals at each end.

The Tricity elements consist of nichrome ribbon wound over thin mica and clamped between thin sheets of mica and metal. The method of winding provides for uniform distribution of heat at any loading.

The Bastian or Quartzalite element consists of a spiral of nichrome wire or ribbon coated with a film of oxide insulation. The spiral is held in or on a tube of quartz. The turns of the spiral may be close together without fear of short circuit. This gives it a "hot rod" appearance.

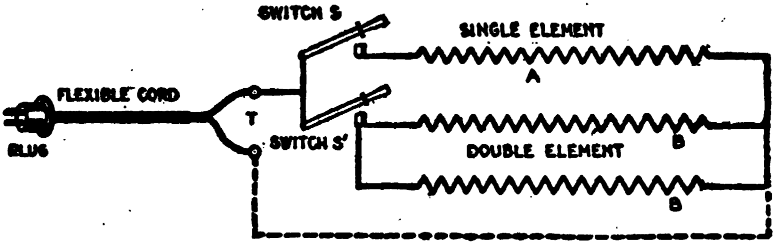


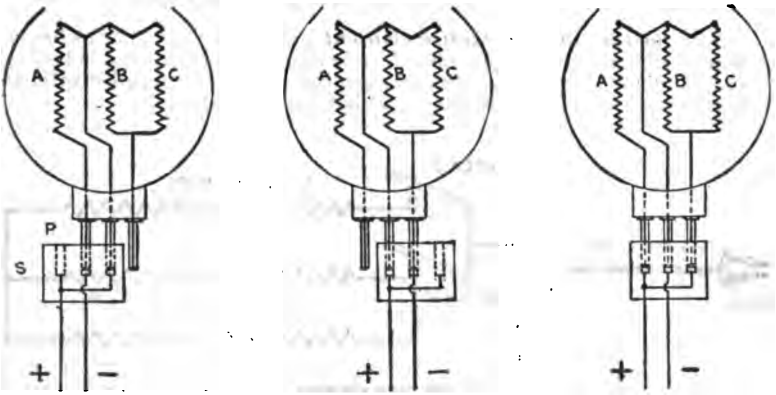
FIG. 5,437.—Arrangement of internal circuit for heaters giving three heating values. *In the diagram,* A represents one third of the heating circuit; BB, two thirds. With switch S on, one-third of full heat is given; with S′, two thirds, while with both S and S′ on, the heater works with full power. At T, are two terminals to which the ends of the flexible cord from the plug are secured.

Temperature Regulation in Electric Heaters.—Many appliances have only one internal circuit so that only one heating value can be obtained. There are, however, a great number which have their resistances divided into two or more parts, which can be connected in different ways, so that several heating values can be obtained.

In the simplest case, the internal circuit consists of two parts of equal heating capacity, each being independently controlled by an ordinary switch, or the two by a double switch, thus permitting operation

1. With either circuit on.
2. With both circuits on.

In some cases the internal circuit is divided into two parts of unequal heating capacity so three heating values can be obtained, by operating



FIGS. 5,438 to 5,440.—Internal circuits of heater. ***As shown*** the heater wires are divided into three sections: A, B, and C, connected to the external terminals P. A three hole socket S, has one conductor of a twin flexible cord connected to the two outer sockets, and the other to the middle socket. The socket piece may thus be put on the pins in three different ways, as shown in the three figures. In fig. 5,438, section A, only of the heater is in circuit; in fig. 3,439, sections B and C are connected, and in fig. 5,440, all sections are in circuit. The signs + and — in each figure indicate the heater end of the flexible cord, the other terminating in a plug connection or switch plug on the wall. In some apparatus, a three or four hole socket is made to fit a corresponding number of pins in one position only, and is connected through a triple or quadruple flexible cord to a two or three way switch adjacent. The various degrees of heat are then obtained by altering the position of the switch.

1. No. 1 circuit alone.
2. No. 2 circuit alone.
3. Both circuits.

Thus, several degrees of control can be obtained by providing enough internal circuit charges.

Room Heating.—Only in a comparatively few instances is electricity employed to advantage in the heating of rooms, such practice being confined chiefly to intermittent auxiliary service in offices and dwellings, ticket booths, or on electric cars where, because of the cheapness of the supply (being generated on a very large scale at the power house), it is desirable for heating. Fig. 5,441 shows the underseat method of car heating and figs. 5,442 to 5,445 the side truss arrangement with wiring diagrams.

HEATING CALCULATIONS

Loss of Heat from Buildings.—To determine the size of a heating plant it is necessary to first estimate the loss of heat

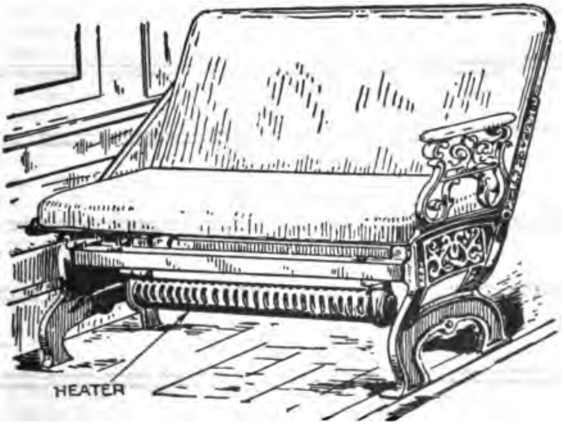


FIG. 5,441.—Underseat method of car heating; view showing seat and placement of heater. At the Montreal meeting of the American Street Railway Association some years ago, Mr. J. F. McElroy read an exhaustive paper on the subject of car heating, from which the following abstracts are taken: In practice it is found that 20,000 *B.t.u.* are necessary to heat an 18 to 20 foot car in zero weather. When the outside temperature is 12½° F., only 16,000 *B.t.u.* are required, etc., which shows the necessity of having electric heaters adjustable. The amount of heat necessary in a car to maintain a given inside temperature depends on: 1, the amount of artificial heat which is given to it; 2, the number of passengers carried. The average person is capable of giving out an amount of heat in 24 hours which is equal to 191 *B.t.u.* This is evidently an error, as Kent says that a person gives out about 400 heat units per hour, and tests by the Bureau of Standards show approximately the same (413) for a person at rest, and about twice that for a man at hard labor (835).

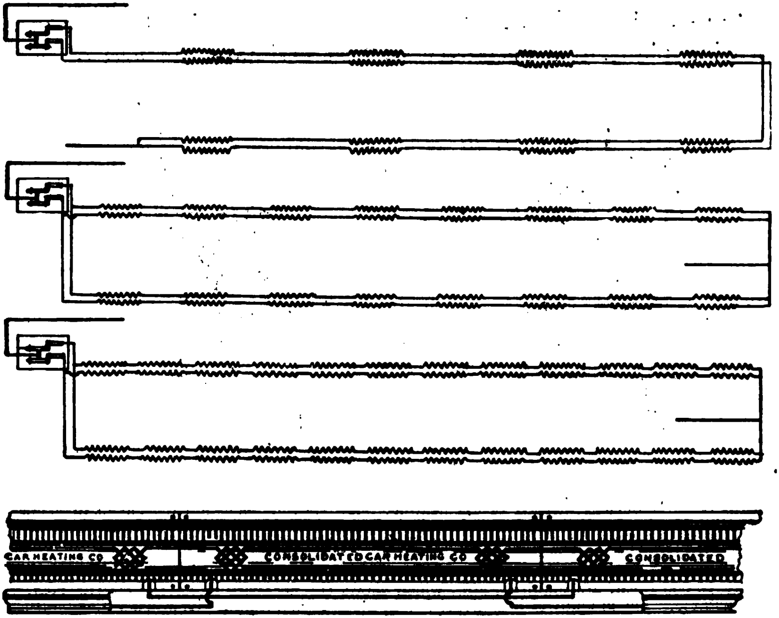
from the building. This is figured on a basis of *B.t.u.* lost per hour. Heat is lost in two ways:

1. By radiation. 2. By convection.

In the first instance, heat is transferred through walls, windows, etc., and lost by radiation, and in the second, it is carried off by the movement of the air as it passes out through the opening in the building.

Values for radiation losses by conduction of heat through various materials such as brick, wood, glass, etc., have been given by various authorities as found by experiment. Although these tests agree closely, the results obtained when the materials have been put together in a building sometimes vary quite widely, due to the quality of the workmanship.

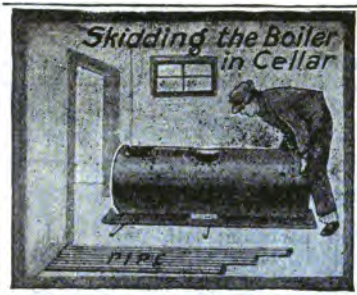
The following table, is compiled by the Gurney Heating Co.

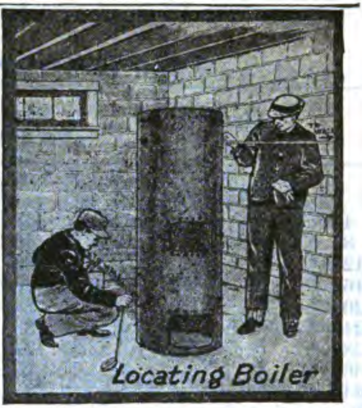


Figs. 5,442 to 5,445.—Wiring diagrams for Consolidated heaters for use along truss plank, and view of truss plank in position showing wiring in moulding. Fig. 5,442, 8 heater equipment; fig. 5,443, 16 heater equipment; fig. 5,444, 24 heater equipment; fig. 5,445, truss plank heater.

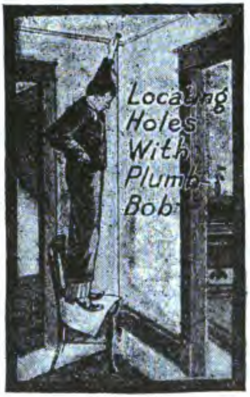
Loss of Heat per Square Foot of Surface

Material	*B.t.u.* per hour
Masonry	
4 inch brick wall	.68
8 " " "	.46
12 " " "	.32
16 " " "	.26
20 " " "	.23
24 " " "	.3
28 " " "	.27
36 " " "	.25
44 " " "	.2
For reinforced concrete add 20 per cent to brick values	
12 inch stone wall, rubber or block masonry	.45
16 inch stone wall, rubber or block masonry	.4
20 inch stone wall, rubber or block masonry	.36
24 inch stone wall, rubber of block masonry	.3
28 inch stone wall, rubber or block masonry	.27
36 inch stone wall, rubber or block masonry	.25
44 inch stone wall, rubber or block masonry	.2
Planks	
1½ inch pine planks	.3
2 " " "	.26
2½ " " "	.23
3 " " "	.2
Windows, Skylights, and Outside Walls	
Single window	1.10
" " double glass	.62
Double "	.50
Single skylight	1.16
¾ inch sheathing and clapboards	.30
¾ inch sheathing, paper and clapboards	.23
Partitions, Floors and Ceilings	
Stud partition, lath and plaster one side	.26
Stud partition, lath and plaster both sides	.15
Ordinary lath and plaster ceiling separating unheated space from heated rooms	.26
Floor, single, thickness ¾ inch, warm air above and cold space below:	
A. No plaster beneath joists	.20
B. Lath and plaster beneath joists	.12
Floor, double, thickness 1½ inches, warm room above and cold space below:	
A. No plaster beneath joists	.13
B. Lath and plaster beneath joists	.08
Miscellaneous	
Wood as flooring	.83
" " ceiling	.104
" " wall	.22
Fire proof flooring	.124
" " ceiling	.145
Cement as flooring	.31
Dirt " "	.23
Wood under slate or composition roof	.3
Wood, under iron	.17
Tile (no boards underneath)	1.25
Cement roof	.6


Skidding the Boiler in Cellar
PIPE



Making Connections at the Boiler
VERTICAL STEEL BOILER


Locating Holes With Plumb Bob

FIGS. 5,446 to 5,450.—Installing an Andrews heating plant.

Example.—What will be the loss of heat in *B.t.u.* per hour in a single room of a brick residence if the temperature inside be maintained at 72 degrees F., when the temperature outside is at 30 degrees, the construction being as follows: 16-inch brick walls; four 3×6 windows, northern and western exposure; fire proof flooring and ceiling; size of room 15×20×14 (high). Area of windows 4×(3×5) = 60

Area of walls 2(15+20)×14—60 = 920 square feet
" " floor 15×20 = 300 " "
" " ceiling 15×20 = 300 " "

Cutting The Riser Holes
Making connections on first floor
Putting up the Expansion Tank
Putting up ceiling plates

Running risers to second floor
Packing Radiator Valve with Candle Wicking

Letting The Air Out Of Radiator

FIGS. 5,451 to 5,457.—Installing an Andrews heating plant —*Continued.*

The values given for heat losses in the table should be increased as follows:

For northeastern, northwestern, western or northern exposure....................20 to 30%.

For rooms 13 to 14½ feet high...........6½%.

For rooms 14½ to 18 feet high............10%.

When building is heated during the day only 30%.

When building remains for long periods without heat.......................................50%.

B.t.u. lost through windows = 60×1.1 ×(72°—32°) = 2,640
" " " walls = 920× .27 ×(72°—32°) = 9,936
" " " floor = 300× .124×(72°—32°) = 1,488
" " " ceiling = 300× .145×(72°—32°) = 1,740

Total loss of heat per hour, normal conditions 15,804 *B.t.u.*

This loss is increased: 30 % by northern and western exposure; 6½ % for high ceiling, that is, total loss of heat per hour under the special condition is:

15,804×1.365 = 21,573 *B.t.u.*

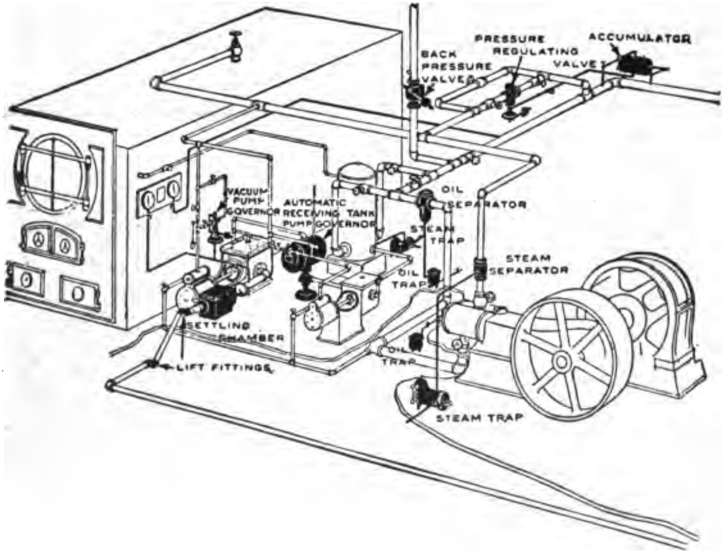


FIG. 5,458.—Van Auken exhaust steam heating system with vacuum distribution showing application to a power plant containing a *closed* feed water heater.

Estimating Radiation.—Repeated tests have shown that the amount of heat given off by ordinary cast iron radiators per square foot of heating surface per hour per degree difference in temperature between the steam or water in the radiator and the air surrounding same to be about 1.6 *B.t.u.* Taking this as a basis a steam radiator under 5 lbs. pressure, corresponding to 228°, which is surrounded by air at 70°, will give off

$$(228^\circ - 70^\circ) \times 1.6 = 253\ B.t.u.$$

commonly taken as

***250 B.t.u.**

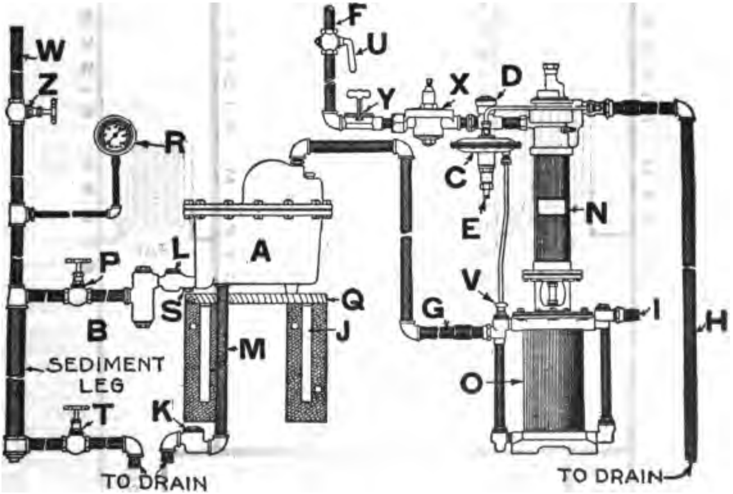


FIG. 5,459.—Bishop-Babcock-Becker hydraulic vacuum pump and equipment. ***The parts are***: A, separator; B, strainer; C, vacuum controller; D, automatic cut-off; E, vacuum adjusting screw; F, water inlet pipe; G, air suction pipe; H, water outlet pipe; I, air outlet; J, bracket; K, check valve; L, check valve; M, separator drain; N, motive cylinder; O, air cylinder; P, globe valve; Q, shelf; R, vacuum gauge; S, separator clean out; T, globe valve; U, water shut-off cock; V, oil cup screw; W, riser to air main; X, water pressure regulator No. 367; Y, water strainer No. 2239; Z, globe valve.

per sq. ft. of heating surface per hour.

With hot water at an average temperature of 160°, the heat given off is

$$(160 - 70) \times 1.6 = 144\ B.t.u.$$

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*NOTE.—The author hopes the size of type here used will cause the reader to remember this item.

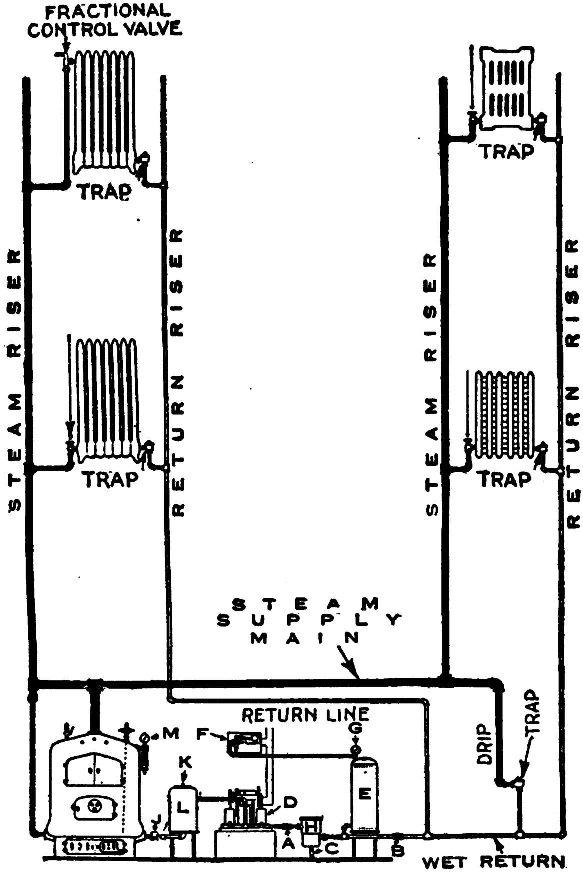


FIG. 5,460.—Bishop-Babcock-Becker return line vacuum heating with electric air pump. Expansion tank E, is connected to wet return line, before it enters strainer. A globe valve B, should be placed on wet return line before it reaches expansion tank connection, so vacuum pump, etc., can be valved off for testing. Vacuum controller F, is connected to expansion tank, and automatic electric switch F, wired to motor and to fuse box. Vacuum gauge G, is installed on expansion tank. Strainer H, is connected to wet return line and to vacuum pump. A globe valve commonly taken as **150** *B.t.u.* per sq. ft. of heating surface per hour.

In a similar manner the heat given off by radiators working at other temperatures may be determined. The following table gives values for the various systems when the air is at 70° Fahr.

Heat Given Off by Radiators

System	Working pressure	Temperature degrees F.	*B.t.u.* per square foot per hour
Steam (low pressure).......	5 lbs. gauge	228	**250**
" (atmospheric)........	0 lbs. "	212	227
" (so called vapor)....	5 in. vacuum	203	213
" (vacuum)...........	10 " "	192	195
" "	15 " "	179	174
" "	20 " "	161	146
Water.....................	....	160	**150**

FIG. 5,460.—*Text continued.*

A, is placed on line between strainer and pump, so pump can be valved off when necessary. The strainer has a globe valve C, on the drain, and this drain is piped to open sewer. Automatic air separating tank L, is connected to air pump, and to boiler. The back pressure valve J, furnished is installed on line between the separating tank and boiler. The air vent K, may be piped to chimney or outside, if desired. *All connections should be made perfectly tight.* The system should be thoroughly tested and cleaned, before being put in operation. Before operating, fully open globe valves A, and B, and close valve C. The air pump is started, as soon as fire under boiler is lighted, and immediately draws air from the system. The pump discharges the air into automatic air separating tank, and it passes out of the air vent. The pump will continue to operate until the desired vacuum is created in system, and then it is automatically stopped by means of the automatic electric switch and vacuum controller. This is usually set to stop pump when 7 inches of vacuum has been created, and start it again when vacuum drops to 5 inches. When steam reaches the traps these thermal members expand thus preventing steam passing into the return line temperature. It is quickly pulled into the radiators, so rapid heating is assured throughout entire system. The instant steam reaches the traps their thermal members expand closing traps, so steam cannot pass into return line. When steam condenses in radiators, condensation at 190 to 198 degrees cools the thermal members, causing them to contract. This opens traps, and *all* condensation and air passes out quickly, after which steam following again expands thermal members closing the traps until more condensation accumulates. The condensation and air after passing out of radiators is drawn out of return piping (assisted by vacuum in expansion tank) through strainer, into vacuum pump. The pump forces condensation and air into automatic air separating tank, and when this tank is full of condensation, and contains a greater pressure than boiler, the back pressure valve opens automatically, allowing condensation to pass into boiler. The air escapes through air vent in separating tank, in manner already described. As condensation never remains in system, there can be no hammering or banging noises, and no danger of freezing. *The parts are;* A, globe valve; B, globe valve; C, globe valve; D, electric air pump; E, expansion tank; F, automatic electric switch and vacuum controller; G, vacuum gauge; H, strainer; J, back pressure valve; K, air vent; L, automatic air separating tank; M, compound gauge.

The values **250** *and* **150** *for low pressure steam and hot water respectively although only approximate, are standard values for ordinary calculations.*

Example.—How many sq. ft. of radiator surface are required to heat the room in the previous example for low pressure steam and hot water radiators

Total heat loss per hour is 22.293 *B.t.u.*

For steam sq. ft. radiator surface $= 22.293 \div 250 = 89$
" hot water " " " $= 22.293 \div 150 = 149$

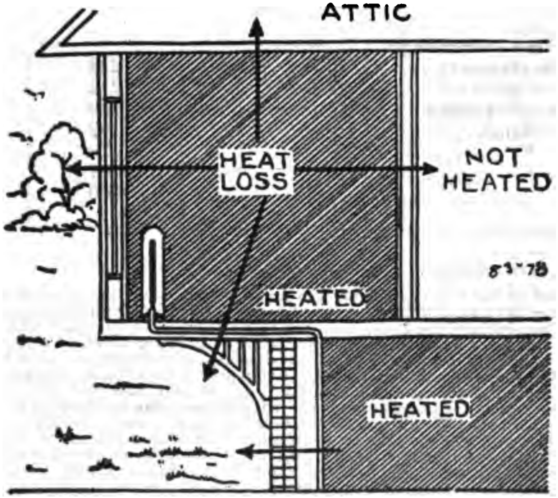


Fig. 5,461.—Heat losses due to exposed floors, ceilings and walls.

Miscellaneous Rules.—There are any number of so called "rules" for quick and approximate calculation and they should be considered only as such in using them. The following are for figuring direct radiation based on wall and glass exposures:

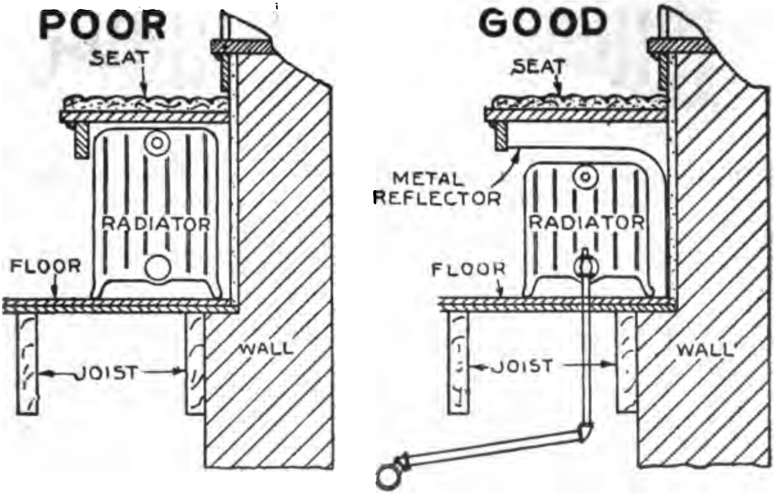
John H. Mills: One square foot of radiating surface for each two square feet of glass, and for each twenty square feet of outside wall, and every two hundred cubic feet of space.

Example:

Glass exposure, square feet,	60;	(1 to 2)	= 30
Wall outside, square feet,	210;	(1 to 20)	= 10½
Cubical contents, cubic feet,	2,016;	(1 to 200)	= 10
Total			50½ sq. ft. steam.

For water, by generally accepted standards, add 60 per cent equals 81 sq. ft.

Professor R. C. Carpenter, Cornell University: To the square feet of glass surface, add one quarter of the exposed wall surface, and $\frac{1}{55}$ to $\frac{3}{55}$ of cubical contents. ($\frac{1}{55}$ for rooms on upper floors, $\frac{2}{55}$ for rooms on first floor, and $\frac{3}{55}$ for large halls); then for steam multiply by .25, and for water by .40.



FIGS. 5,462 and 5,463.—Wrong and right way to install radiator under seat.

Example.—Room as above.

Glass exposure, 60 square feet, to which add one-quarter of wall 210÷4 = 53, to which add (room first floor) $\frac{2}{55}$ cubical contents—$\frac{2}{55}$×2,016 = 73. Thus 60×53×73 = 186×.25 (for steam) = 47 square feet; or, 186 ×.40 (for water) = 74 square feet.

FIGS. 5,464 and 5,465.—American Radiator two and three column "Peerless" radiators.

Peerless Two-Column Radiators

For Steam and Water

No. of Sections	* Length 2½ in. per Sec.	HEATING SURFACE—SQUARE FEET					
		45-in. Height 5 Sq.Ft. per Sec.	38-in. Height 4 Sq.Ft. per Sec.	32-in. Height 3⅓ Sq.Ft. per Sec.	26-in. Height 2⅔ Sq.Ft. per Sec.	23-in. Height 2⅓ Sq.Ft. per Sec.	20-in. Height 2 Sq.Ft. per Sec
2	5	10	8	6⅔	5⅓	4⅔	4
3	7½	15	12	10	8	7	6
4	10	20	16	13⅓	10⅔	9⅓	8
5	12½	25	20	16⅔	13⅓	11⅔	10
6	15	30	24	20	16	14	12
7	17½	35	28	23⅓	18⅔	16⅓	14
8	20	40	32	26⅔	21⅓	18⅔	16
9	22½	45	36	30	24	21	18
10	25	50	40	33⅓	26⅔	23⅓	20
11	27½	55	44	36⅔	29⅓	25⅔	22
12	30	60	48	40	32	28	24
13	32½	65	52	43⅓	34⅔	30⅓	26
14	35	70	56	46⅔	37⅓	32⅔	28
15	37½	75	60	50	40	35	30
16	40	88	64	53⅓	42⅔	37⅓	32
17	42½	85	68	56⅔	45⅓	39⅔	34
18	45	90	72	60	48	42	36
19	47½	95	76	63⅓	50⅔	44⅓	38
20	50	100	80	66⅔	53⅓	46⅔	40
21	52½	105	84	70	56	49	42
22	55	110	88	73⅓	58⅔	51⅓	44
23	57½	115	92	76⅔	61⅓	53⅔	46
24	60	120	96	80	64	56	48
25	62½	125	100	83⅓	66⅔	58⅓	50
26	65	130	104	86⅔	69⅓	60⅔	52
27	67½	135	108	90	72	63	54
28	70	140	112	93⅓	74⅔	65⅓	56
29	72½	145	116	96⅔	77⅓	67⅔	58
30	75	150	120	100	80	70	60
31	77½	155	124	103⅓	82⅔	72⅓	62
32	80	160	128	106⅔	85⅓	74⅔	64

Peerless Three-Column Radiators

For Steam and Water

No. of Sections	* Length 2½ in. per Sec.	HEATING SURFACE — SQUARE FEET					
		45-in. Height 6 sq. ft. per Sec.	38-in. Height 5 sq. ft. per Sec.	32-in. Height 4½ sq. ft. per Sec.	26-in. Height 3¾ sq. ft. per Sec.	22-in. Height 3 sq. ft. per Sec.	18-in. Height 2¼ sq. ft. per Sec.
2	5	12	10	9	7½	6	4½
3	7½	18	15	13½	11¼	9	6¾
4	10	24	20	18	15	12	9
5	12½	30	25	22½	18¾	15	11¼
6	15	36	30	27	22½	18	13½
7	17½	42	35	31½	26¼	21	15¾
8	20	48	40	36	30	24	18
9	22½	54	45	40½	33¾	27	20¼
10	25	60	50	45	37½	30	22½
11	27½	66	55	49½	41¼	33	24¾
12	30	72	60	54	45	36	27
13	32½	78	65	58½	48¾	39	29¼
14	35	84	70	63	52½	42	31½
15	37½	90	75	67½	56¼	45	33¾
16	40	96	80	72	60	48	36
17	42½	102	85	76½	63¾	51	38¼
18	45	108	90	81	67½	54	40½
19	47½	114	95	85½	71¼	57	42¾
20	50	120	100	90	75	60	45
21	52½	126	105	94½	78¾	63	47¼
22	55	132	110	99	82½	66	49½
23	57½	138	115	103½	86¼	69	51¾
24	60	144	120	108	90	72	54
25	62½	150	125	112½	93¾	75	56¼
26	65	156	130	117	97½	78	58½
27	67½	162	135	121½	101¼	81	60¾
28	70	168	140	126	105	84	63
29	72½	174	145	130½	108¾	87	65¼
30	75	180	150	135	112½	90	67½
31	77½	186	155	139½	116¼	93	69¾
32	80	192	160	144	120	96	72

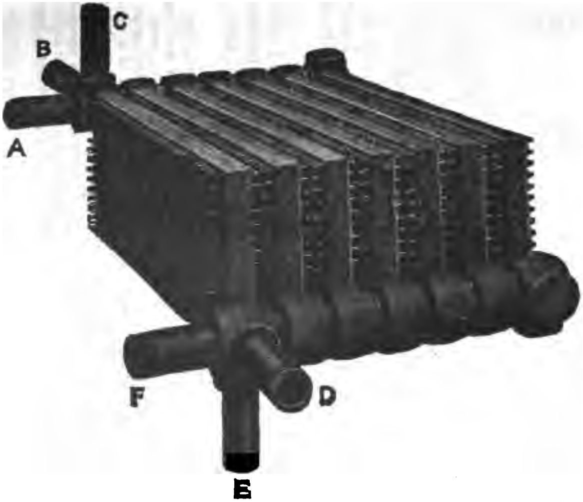


FIG. 5,466.—United States pin indirect radiator for steam or hot water. Heating surface 10 sq. ft. per section. Tappings can be made at A, B, C, D, E, or F, but are regularly made at F. These tappings are: pin, 10 ft. section as above, 1½ in.; pin 15 and 20 ft. sections 2 ins.

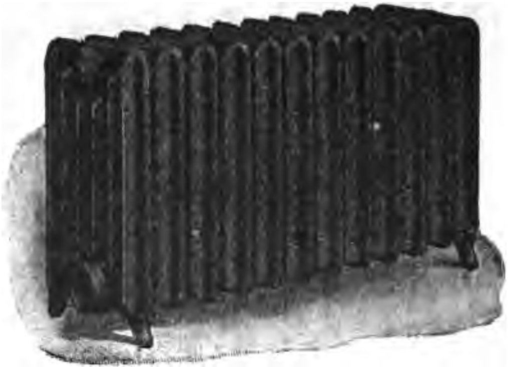


FIG. 5,467.—American Radiator Co. "Peerless" radiator.

Peerless Window Radiators

No. of Sections	Length 3 Inches per Section	HEATING SURFACE.— SQUARE FEET		
		20-in. Height 5 sq. ft. per Section	16-in. Height 3¾ sq. ft. per Section	13-in. Height 3 sq. ft. per Section
2	6	10	7½	6
3	9	15	11¼	9
4	12	20	15	12
5	15	25	18¾	15
6	18	30	22½	18
7	21	35	26¼	21
8	24	40	30	24
9	27	45	33¾	27
10	30	50	37½	30

Mott Iron Works.—While the radiating surface which will be required in any room largely depends upon the proportion of exposed wall and glass surface, there must, however, be some relation to the cubical content of same. Hence, as the simplest and most readily comprehended rule of apportioning radiation the following table is given as representing the experience of the best heating engineers:

Radiation Tables

(For steam and hot water)

Dwellings	Cu. ft. of space using steam	Cu. ft. of space using hot water
Living rooms, one side exposed.........	50 to 55	25 to 30
" " two sides "	45 " 50	20 " 25
" " three " "	40 " 45	15 " 20
Sleeping "	50 " 70	30 " 35
Halls and bath rooms..................	40 " 50	20 " 30
Public Buildings		
Offices................................	50 " 25	30 " 40
Schools................................	40 " 60	20 " 30
Factories and stores....................	70 " 100	40 " 60
Assembly halls and churches............	100 " 150	60 " 80

For direct-indirect *steam* radiation, add 25%, and for indirect, 60%, to the amount of direct surface to secure equal value of heating surface.

For direct-indirect *water* radiation, add 33⅓%, and for indirect, 75%, to the amount of direct surface to secure equal value of heating surface.

Allowances should be made for extraordinary conditions such as character buildings, location, exposure, and quality of construction, loose windows and doors and unusual glass exposure, and the necessary lengths of distributing mains.

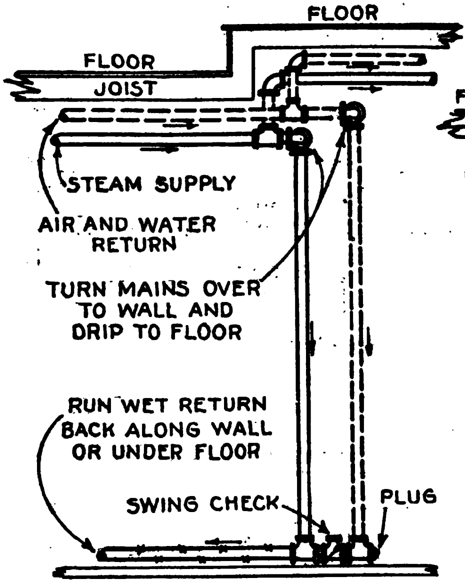
In apportioning the amount of indirect surface to be used in connection with a heating system, it should be remembered that this manner of heating should be in connection with some system of ventilation, and therefore

---

NOTE.—***Tapping radiators.*** Steam or vapor is lighter than air or water, and, therefore, by introducing the lighter element, steam, at the top of a radiator and removing the heavier elements, air and water, from the bottom, the laws of nature are followed, and accelerated circulation results. Radiator valves are easier to get at, when at the top of a radiator, also. Tapping the supply and return at one end facilitates the removal of a radiator or increasing its size, if building changes make it necessary, by adding sections to the opposite end without disturbing pipe connections. Bear in mind that the efficiency of the radiating surface determines the tapping, and not the size or surface alone. Pipe coils require special consideration to secure adequate steam supply. The supply connections must also be arranged to give each pipe its proper supply of steam. Failure to observe certain requirements has given pipe coils a bad reputation as radiators.

a larger volume of air must be warmed than when using direct radiation, and proportionately with the system of ventilation. In buildings with a medium provision for ventilation, it is a good practice to add 75 per cent to that which would be required in direct surface to obtain the amount of indirect required.

Indirect Heating.—The amount of heat given off by an indirect radiator depends upon:


FLOOR
FLOOR
JOIST
STEAM SUPPLY
AIR AND WATER RETURN
TURN MAINS OVER TO WALL AND DRIP TO FLOOR
RUN WET RETURN BACK ALONG WALL OR UNDER FLOOR
SWING CHECK
PLUG

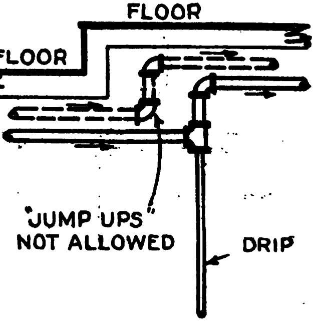


FIG. 5,468.—Correct method of rising to a higher level with drips into a wet return. No "jump ups" allowed without dripping as shown.

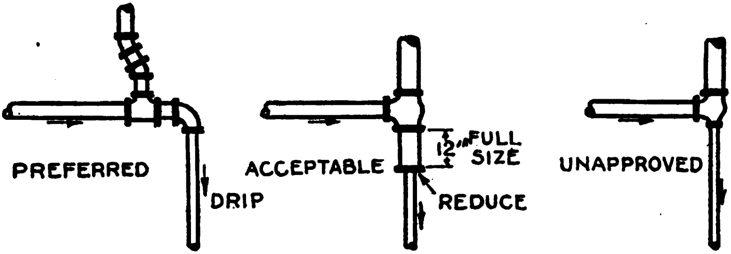
FIG. 5,469.—Improper methods.

1. The difference between the temperature of the steam or water in the radiator and that of the air.

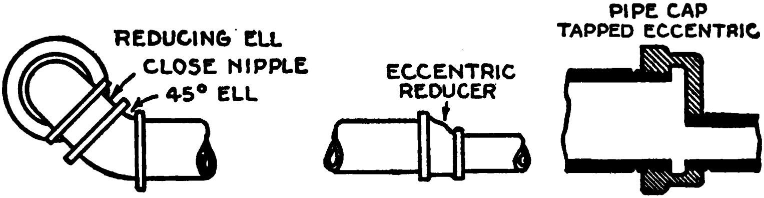
2. The velocity of the air passing over the radiator.

Under ordinary conditions, the indirect radiator will give off 2 heat units per hour for each degree difference in temperature between steam or water and the air. In house work it is safe to figure from 400 to 420 *B.t.u.* for steam and from 300 to 350 *B.t.u.* for water per square foot of surface per hour. In school house work, owing to larger volume and higher velocity of the air, the efficiency is calculated at about 600 heat units.

Size of Mains.—The steam main can be determined by taking the total amount of direct radiation to which add 25 per cent for piping, and from this total extract the square root, dividing same by 10, which gives the size of main to use. This is for one pipe work. For two pipe work, one size less is sufficient, and the return can be one or two sizes less than the supply. A steam main should not decrease in size according to the area of its branches, but very much slower.



Figs. 5,470 to 5,472.—Methods of rising with large mains to upper floors.



Figs. 5,473 to 5,475.—Three ways of reducing eccentric. Fig. 5,473, used at turns; figs. 5,474 and 5,475, used on straight runs.

Example.—Having 500 feet of direct radiation add to it 25 per cent or 125, which equals 625. The square root of this is 25, which divided by 10 gives 2½, or the size of the pipe. For handy reference and practical use the following table can be used, though not not exactly in accord with the foregoing.*

Size of Steam Mains

Radiation	One-pipe work	Two-pipe work
125 square feet	1½ inch	1¼×1 inch
250 “ “	2 “	1½×1¼ “
400 “ “	2½ “	2 ×1½ “
650 “ “	3 “	2½×2 “
900 “ “	3½ “	3 ×2½ “
1,250 “ “	4 “	3½×3 “
1,600 “ “	4½ “	4 ×3½ “
2,050 “ “	5 “	4½×4 “
2,500 “ “	6 “	5 ×4½ “
3,600 “ “	7 “	6 ×5 “
5,000 “ “	8 “	7 ×6 “
6,500 “ “	9 “	8 ×6 “
8,100 “ “	10 “	9 ×6 “

Sizes of Hot Water Mains

Radiation	Pipe
75 to 125 square feet	1¼ inch
125 “ 175 “ “	1½ “
175 “ 300 “ “	2 “
300 “ 475 “ “	2½ “
475 “ 700 “ “	3 “
700 “ 950 “ “	3½ “
950 “ 1,200 “ “	4 “
1,200 “ 1,575 “ “	4½ “
1,575 “ 1,975 “ “	5 “
1,975 “ 2,375 “ “	5½ “
2,375 “ 2,850 “ “	6 “

In hot water, flow mains may be reduced in size in proportion to the branches taken off. They should, however, have as large area as the sum of all branches beyond that point. It is advisable that the horizontal branches be one size larger than the risers. Returns should be same as flows.

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* NOTE—As recommended by the William Page Boiler Co., New York.

Table of Mains and Branches

Main			Branch
1 in.	will supply		...2 .... ¾ in.
1¼ in.	"	"	...2 .... 1 in.
1½ in.	"	"	...2 .... 1¼ in.
2 in.	"	"	...2 .... 1½ in.
2½ in.	"	"	...2, 1½ in. and 1, 1¼ in., or 1, 2 in. and 1, 1¼ in.
3 in.	"	"	...1, 2½ in. and 1, 2 in., or 2, 2 in. and 1, 1½ in.
3½ in.	"	"	...2, 2½ in. or 1, 3 in., and 1, 2 in. or 3, 2 in.
4 in.	"	"	...1, 3½ in. and 1, 2½ in., or 2, 3 in. and 4, 2 in.
4½ in.	"	"	...1, 3½ in. and 1, 3 in., or 1, 4 in. and 1, 2½ in.
5 in.	"	"	...1, 4 in. and 1, 3 in., or 1, 4½ in. and 1, 2½ in.
6 in.	"	"	...2, 4 in. and 1, 3 in., or 4, 3 in. or 10, 2 in.
7 in.	"	"	...1, 6 in. and 1, 4 in., or 3, 4 in. and 1, 2 in.
8 in.	"	"	...2, 6 in. and 1, 5 in., or 5, 4 in. and 2, 2 in.

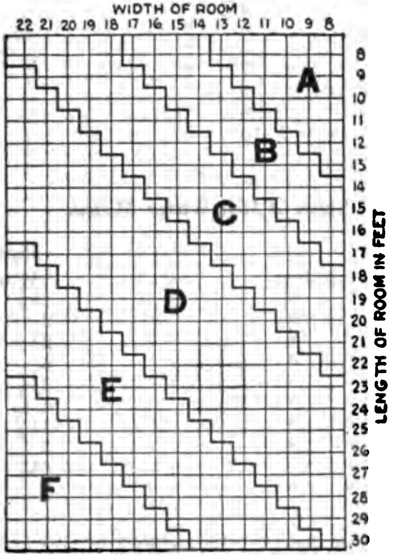


FIG. 5,476.—Diagram showing sizes of pipes required for heating rooms with warm air. ***To use the diagram,*** note where the intersection of width and length lines fall, and the sizes of piping required is indicated by the letter within the enclosed heavy lines as follows: **A,** 1st floor 8 in. basement pipe; 2nd floor 8 in. basement 3½′×10″ riser; **B,** 1st floor 9 in. basement pipe; 2nd floor 8 in. basement 3½″×11½″ riser; **C,** 1st floor 10 in. basement pipe; 2nd floor 9 in. basement 3½″×11½″ riser; **D,** 1st floor 12 in. basement pipe; 2nd floor 10 in. basement 5″×14″ riser; **E,** 1st floor 14 in. basement pipe; 2nd floor 12 in. basement 8″×14″ riser. NOTE—Rooms from 8 to 15 ft. in width assumed to have not over 10 ft. ceilings. Rooms 15 to 22 ft. wide not over 12 ft. ceilings.

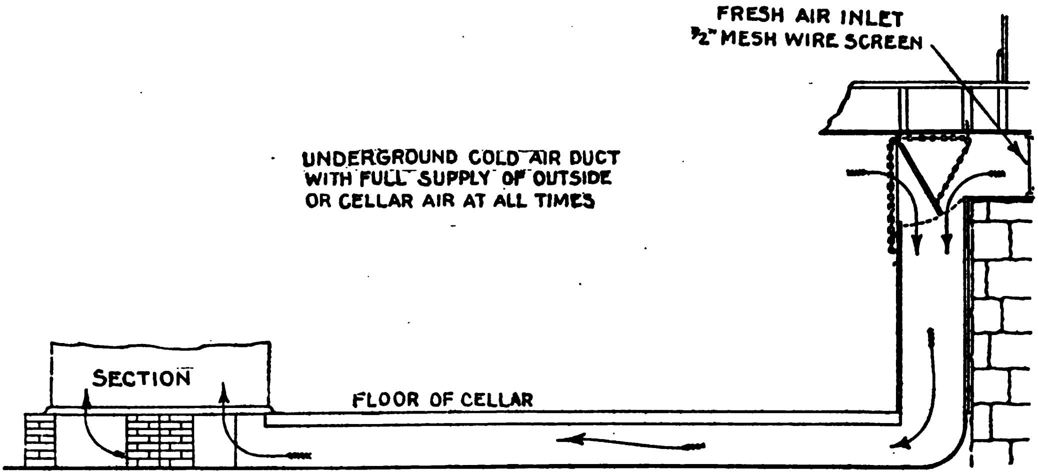

FRESH AIR INLET
½" MESH WIRE SCREEN
UNDERGROUND COLD AIR DUCT
WITH FULL SUPPLY OF OUTSIDE
OR CELLAR AIR AT ALL TIMES
SECTION
FLOOR OF CELLAR

FIG. 5,477.—Proper method of installing cold air box in connection with duct when air is taken from cellar and from outside the house.

Hot Air Pipes.—In hot air furnace heating, the size of hot air pipe required for any room depends much on conditions, that is, construction of building, exposure, wall and glass surface, length of warm air pipe, elevation of same, etc.

One manufacturer of hot air furnaces gives the following rule for finding the size of pipe to heat any room:

***Rule.**—The pipe must contain as much cross sectional area in sq. ins. as there are square feet of glass surface plus 5 per cent of outside wall surface plus 1 per cent of cubical contents of room.*

Example.—What size hot air pipe is required for a room 10 feet wide, 12 feet long, 9 feet high, with two sides exposed and having three windows 2 feet 6 inches wide and 6 feet high:

Room 10 feet wide, 12 feet long, 9 feet high, with two sides exposed and having three windows 2 feet 6 inches wide and 6 feet high:

Glass surface 2½×6×3 equals		45 sq. ft.
Wall surface 10 ×9 equals	90	
Wall surface 12 ×9 equals	108	
	198	
Less glass surface	45	153 sq. ft.
Cubical contents 10×12×9 equals		1,080 cu. ft.
One square inch for each foot of glass surface		45 sq. ins.
5 per cent of exposed wall surface		8 " "
1 per cent of cubical contents		10 " "
Total		63 " "

The size of pipe for above room must contain 63 square inches, therefore use a 9 inch round pipe.

For second story rooms use same rule and deduct 15 per cent from pipe capacity.

For rooms necessitating long runs of pipe always figure a pipe one inch larger in diameter.

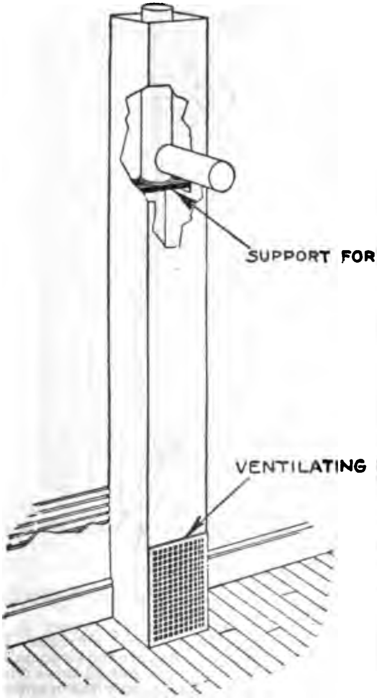
To Find Size of Hot Air Furnace.—The capacity of hot air furnaces is rated in terms of maximum (cross sectional) area of piping in inches which furnace will supply. Accordingly, to find the size furnace required to heat a residence use the rule just given for finding the different sizes of pipes necessary to heat the rooms and the sum of the area of these pipes will determine the size furnace required.

Example.—A house having nine rooms requiring the following size pipes:

2—12-inch equals	226 sq. ins. capacity
3—10- " "	234 " " "
2— 9- " "	126 " " "
2— 8- " "	100 " " "
Total capacity of pipes	686 " " "

This house would require a furnace having a pipe capacity of at least 686 square inches; use the furnace nearest to this in greater capacity, say 700 square inches.

Ventilation.—The respiration of one adult person will vitiate hourly about 500 cu. ft. of air, to which should be added vitiation from other sources, such as moisture from the body, methods of illumination, etc., making a requirement of about



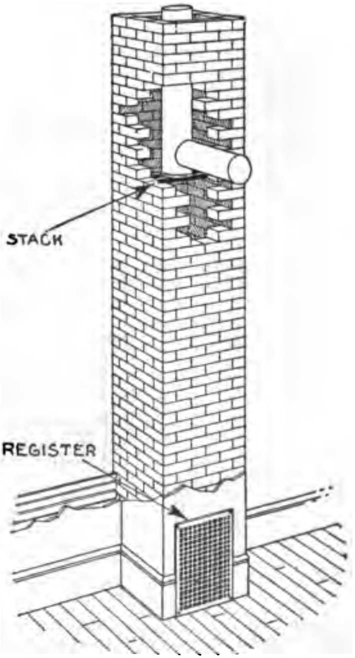


Fig. 5,478.—Galvanized iron duct used in lieu of chimney, showing ventilating register and steel smoke stack.

Fig. 5,479.—Brick chimney with ventilating register at bottom and steel smoke stack as used in fig. 5,480.

1,000 cubic feet per hour of fresh air for each adult person in average living rooms and places of assembly.

The atmosphere of rooms is changed partly by diffusion, but chiefly and effectively by positive currents—the supply of fresh air through registers, connecting with the outside and becoming warmed as it passes over and through the intervening radiators—

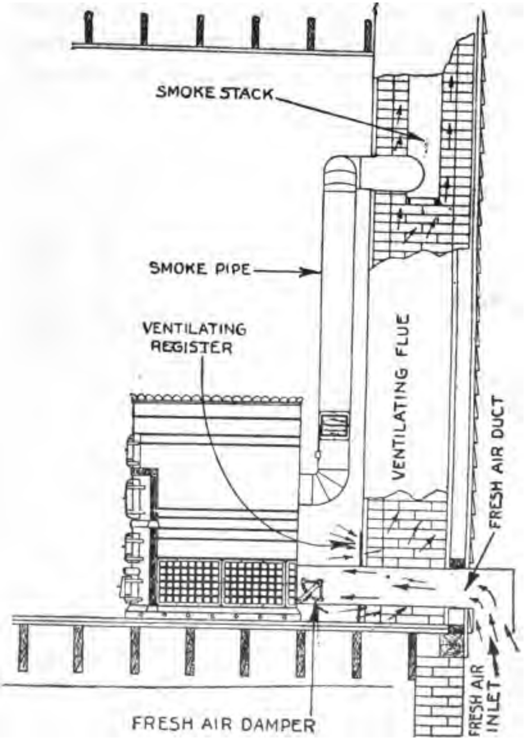


FIG. 5,480.—Mueller hot air furnace installation showing vent flue and fresh air duct. The cold air near the floor is drawn through grilles at bottom of heater casing into the air chambers where it is heated. In the case of halls, schools, etc., at night and in fact at all times pupils are not assembled the outer air supply should be shut off and the air supply taken entirely from the room, thus materially saving fuel and the discharge of the foul air into flues provided for it. A common and most effective means in domestic ventilation is the chimney, through an open fire place, or a special flue in proximity to it is rendered most effective by the incident heat of the chimney. The opening to this flue should be at the bottom, practically on a line with the floor.

The fresh air from the outside passes through registers at a velocity from 200 to 300 feet per minute. The clear openings of a register will be approximately two-thirds of its full area; thus a 12 by 15 register would have an available area of 120 inches. The fresh, warm air, passing at this rate per minute, would supply from 10,000 to 15,000 cubic feet an hour, and meet the requirements of a family of from 10 to 15 persons.

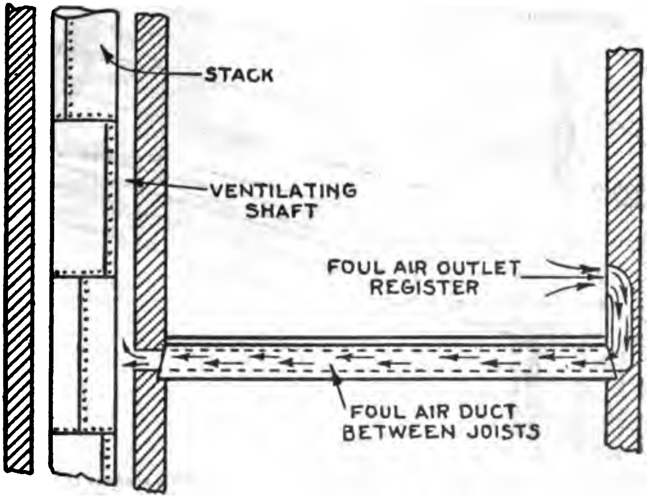
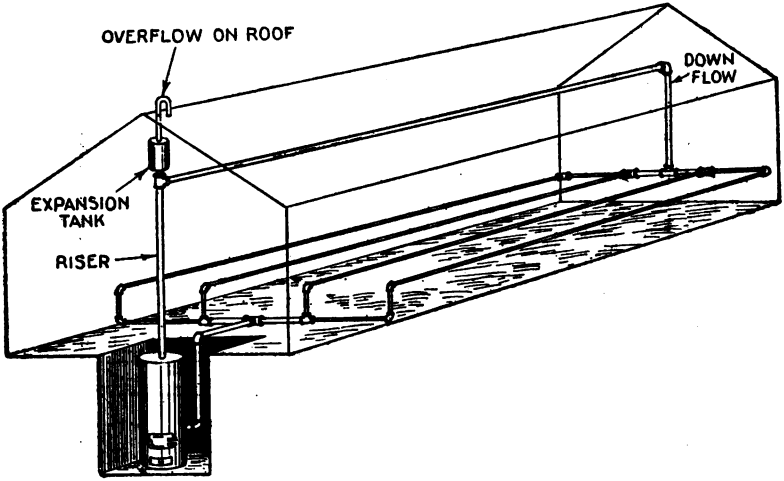


FIG. 5,481.—Method of connecting foul air duct between joists to ventilating shaft.

The requirements of Massachusetts Laws in the ventilation of school rooms is 30 cubic feet of fresh air per minute for each pupil. Thus, the average room providing for 50 pupils would require 1,500 cubic feet per minute, or 90,000 cubic feet per hour. Contemplating a movement of the air at the rate of 5 feet per second, and supply and exhaust registers—2 by 2½ feet each—or an area of 5 square feet will insure the desired result.

For churches and general assembly halls, the requirement is 15 cubic feet per minute for each person.



,482.—Overfed water heating system for green house. ***In this system*** the hottest pipes being in the most exposed portions of the house, the cold air is, which finds entrance through or around the ventilators or through the laps in the glass, tempered, thus tending to a nearer uniform heating effect. The expansion tank is placed above the high point of the system, and for which there should be pitch along the upper pipes and returns to facilitate circulation and allow for proper drainage.

Green House Heating.—In heating green houses, glass or its equivalent is the only factor considered. If amount of glass be not known, multiply the length of the house by its breadth and add ⅓ to get glass surface; ⅓ equals the ends and pitch of roof. Reduce wall surface to glass equivalent by dividing by 4 and

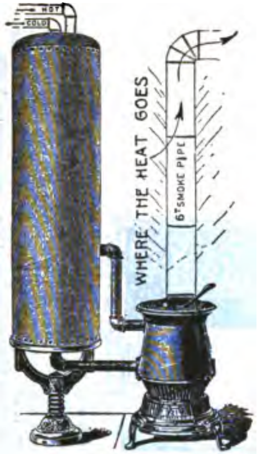


Fig. 5,483.—Usual method of setting up a heating stove to a range boiler. These "heating" stoves cannot be too strongly condemned unless one wishes to employ a long length of stove pipe to heat the room The efficiency of this method of heating water, even with the low rate of combustion ordinarily employed is very low because a ridiculously small amount of heating surface is provided in proportion to the grate area.

add to the glass surface. The heating surface required will be found by dividing this total glass equivalent by the factors in the following table by John J. Hogan:

This table is computed for zero weather; for lower temperatures add 1½% for each degree below zero. A green house requiring 200 feet of surface at zero should have 230 square feet at 10° below zero.

Heating Surface Factors for Green House Heating

Temperature of air in house	Temperature of water in heating pipes				Steam
	140°	160°	180°	200°	Three lbs. pressure
	Square feet of glass and its equivalent proportion to one square foot of surface in heating pipes or radiator.				
40°	4.33	5.25	6.66	7.69	8.
45°	3.63	4.65	5.55	6.66	7.5
50°	3.07	3.92	4.76	5.71	7.
55°	2.63	3.39	4.16	5.	6.5
60°	2.19	2.89	3.63	4.33	6.
65°	1.86	2.53	3.22	3.84	5.5
70°	1.58	2.19	2.81	3.44	5.
75°	1.37	1.92	2.5	3.07	4.5
80°	1.16	1.63	2.17	2.73	4.
85°	.99	1.42	1.92	2.46	3.5

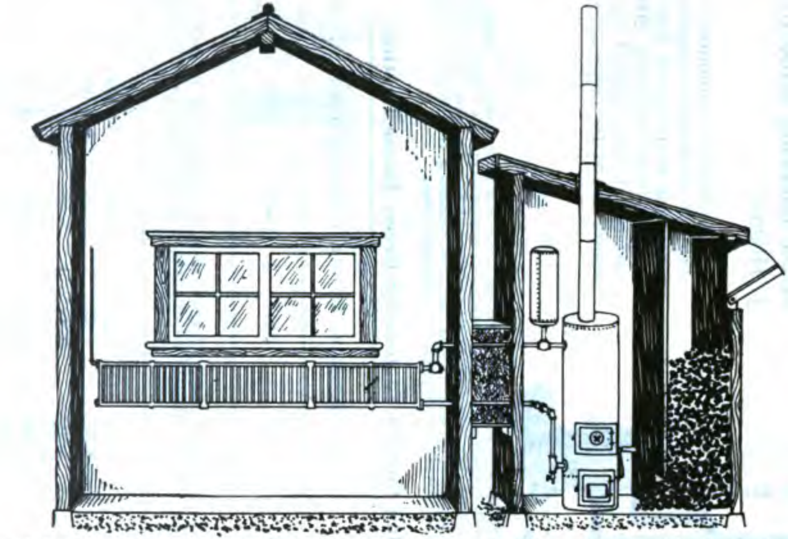


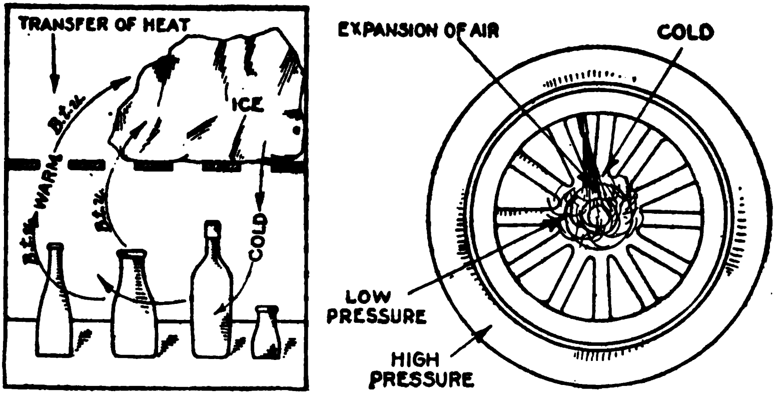
FIG. 5,484.—Small hot water heating installation for a garage. ***In many cities*** and communities the fire laws and regulations will not permit of an open fire in the same room with the car. The majority of fire insurance policies also prohibit the presence of a naked flame where there is a quantity of gasoline. To meet such requirements the boiler may be placed in an outside small building as shown, or in a "lean to." The circulating pipes when the boiler house is separate are protected from exposure to the elements by a simple boxing filled with insulating material. Where there is any regard for fuel economy a vertical tubular boiler will be installed (as here shown and more in detail on page 2,136), rather than the coal eating rig shown on page 3,009.

CHAPTER 84

REFRIGERATION

By definition, refrigeration is the process of lowering the temperature of a body, or of keeping the temperature below that of the atmosphere. Low temperatures may be produced:

1. By transfer of heat from a warm to a cold body,



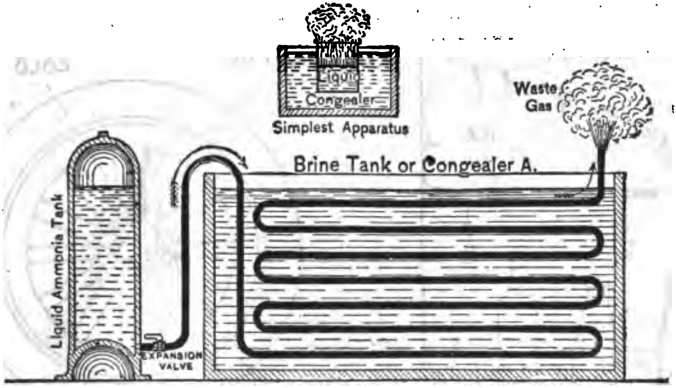
FIGS. 5,485 and 5,486.—Methods of refrigeration, fig. 5,485, by transfer of heat from a warm to a cold body; fig. 5,486, by expansion of a gas. Fig. 5,485 shows the familiar process which takes place inside an ice box, and fig. 5,486, what happens when the valve inside is suddenly removed from a tire.

As for instance in an ice box, the ice will absorb an amount of heat from the warm air in amount equal to the latent heat of fusion of the ice (142 *B.t.u.* per lb. of ice), when the ice will melt, thus cooling the air and provisions contained in the ice box.

2. By expansion of a gas.

If work be done by a gas under pressure, as in pushing a piston by expanding, this work must be done at the expense of the energy contained in the gas, and the temperature of the gas will fall. This can be verified by placing the hand in the exhaust from an engine operating on compressed air which will be found to be considerably colder than the surrounding air. The same thing is illustrated by removing the valve from an auto or bicycle tire and allowing the air to suddenly expand by escaping into the atmosphere, the escaping air will feel cold to the hand. In this case ***work is done by the air as it expands*** because it pushes back the surrounding atmosphere to make room for itself against an absolute pressure of 14.7 lbs. per sq. in., hence the temperature of the air is lowered.

3. By evaporation of liquids having low boiling points.



FIGS. 5,487 and 5,488.—Refrigeration by evaporation of ammonia. The ammonia tank containing ammonia under pressure is connected to the evaporating coil by means of the expansion valve. The liquid through its evaporation takes up heat from the contents of the congealer. Such an arrangement as shown here would not be practical in actual practice as the gas is allowed to go to waste and in order to use it over again more apparatus than shown here has to be used.

When a liquid evaporates (that is, changes from a liquid to a gas), it will absorb from its surroundings an amount of heat equal to its latent heat of vaporization, commonly called simply its *latent heat*. During this process or transfer of heat by *change of state* of the water to gas, its temperature remains constant, but the temperature of the surroundings is lowered. The refrigerating effect or amount of heat which may be transferred in this way is considerable as compared with the melting of ice or expansion of a gas, hence it is the method generally used. Thus, water, although it requires only 180 *B.t.u.* to raise its temperature from the freezing to the boiling point, will absorb 970.4 *B.t.u.* (at atmospheric pressure), per lb. in changing its state from a liquid to a gas, that is, in changing from water to steam.

Since nearly all systems depend upon the latent heat of the heat absorbing medium used to produce the refrigerating effect, it is therefore necessary, in order to get a clear conception of refrigeration principles, to properly understand the meaning of the term *latent heat*. This is explained at length in other volumes of this series.*

The numerous systems of refrigeration may be classified according to several points of view as:

1. With respect to the heat absorbing medium or cooling agent employed as:

1. Ammonia.
2. Carbonic acid.
3. Sulphur dioxide.
4. Pictet fluid.
5. Sulphuric ether.
6. Methylic ether.
7. Ethyl chloride.
8. Air.

2. With respect to the working of the heat absorbing medium or cooling agent as:

a. ***Compression*** $\left\{\begin{matrix}\text{wet}\\ \text{dry}\end{matrix}\right.$

b. ***Absorption***

3. With respect to the manner of applying the refrigeration as:

a. Direct expansion.
b. So called indirect expansion or brine circulating.
c. Semi-indirect expansion or brine congealing.
d. Cold air.
e. Pipe line.

Ques. What two systems are most extensively used?

Ans. The ammonia compression system and the ammonia absorption system.

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* NOTE.—See Chapter 1, Basic Principles, vol. 1; Chapter 55, "From Ice to Steam," vol. 5.

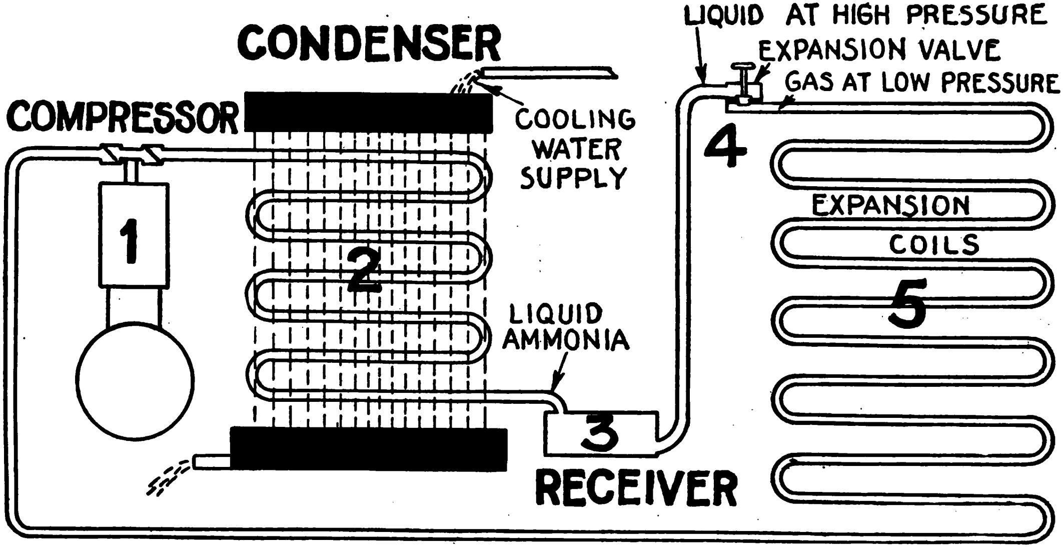


FIG. 5,489.—Elementary ***ammonia compression system; direct expansion.*** ***The essential parts are:*** 1, compressor; 2, condenser; 3, receiver; 4, expansion valve; 5, expansion coils. From the discharge valve of the compressor to the expansion valve is the *high pressure* portion of the system, and from the expansion valve to the suction valve of the compressor, the low pressure portion. ***Cycle of operation:*** 1, compressor compresses ammonia gas to about 150–170 lbs.; 2, gas is cooled in condenser and condenses, passing into receiver in a liquid state; 3, pressure is reduced by throttling in passing through expansion valve, causing vaporization of the liquid ammonia; 4, the latent heat of vaporization is absorbed from surrounding substances in passing through the expansion coils producing the refrigeration effect; 5, ammonia gas returns to compressor, thus completing the cycle.

Ammonia Compression System.—The anhydrous ammonia used in this system is, in its natural state, at atmospheric pressure and ordinary temperature, a gas. In fig. 5,490, the essential elements of the system are: 1, compressor; 2, condenser; 3, receiver; 4, expansion valve, and 5, expansion coils.

In operation the compressor takes the ammonia in the form of gas from the expansion coils and compresses this gas to a pressure of about 150 to 170 lbs. pressure into the condenser, and as it strikes the cool surfaces of the condenser, cooled by cold water circulating over the pipes of the condenser, the gas gives up the heat which it absorbed in the expansion coils and that imparted to it by the work of the compressor and is condensed, that is, becomes a liquid.

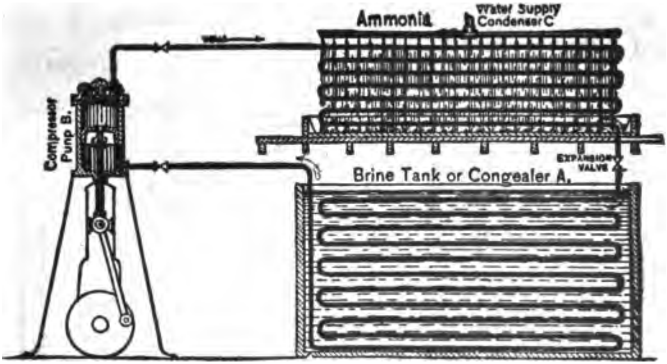


FIG. 5,490.—Diagram showing the essentials of a mechanical *compression system* with vertical compressor. The condenser shown is of the atmospheric type, and the brine circulating system is used, the brine being cooled by the expansion coils in a tank and then circulated through pipes in the refrigerating rooms.

The liquid ammonia passes from the condenser to the receiver from which it is admitted into the expansion coils at a lower pressure by throttling on passing through the expansion valve.

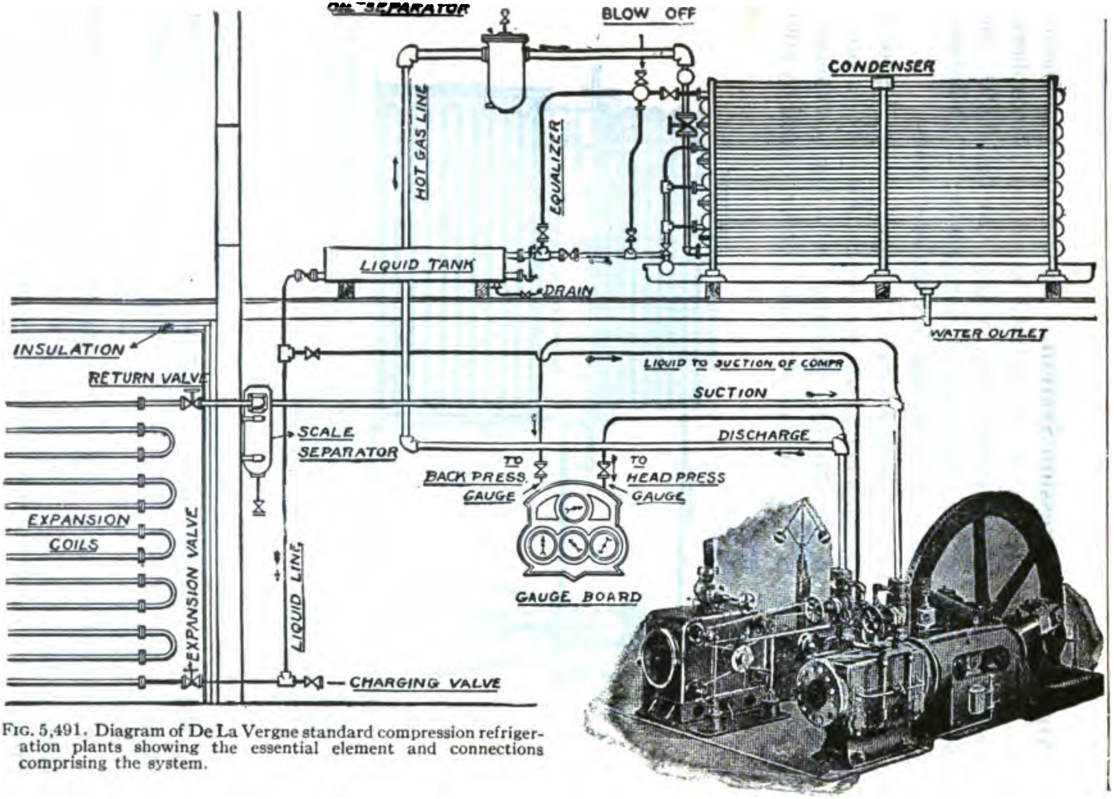


FIG. 5,491. Diagram of De La Vergne standard compression refrigeration plants showing the essential element and connections comprising the system.

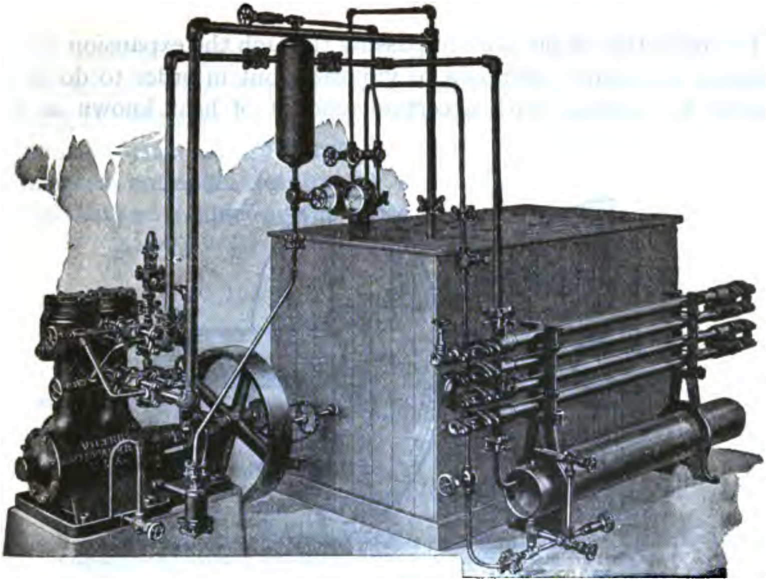
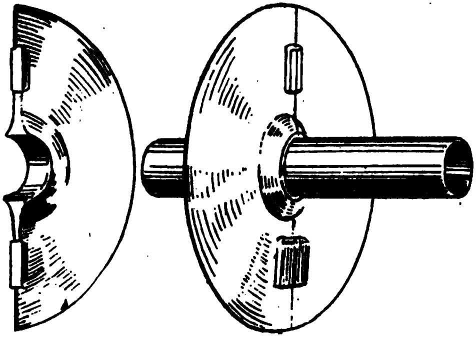


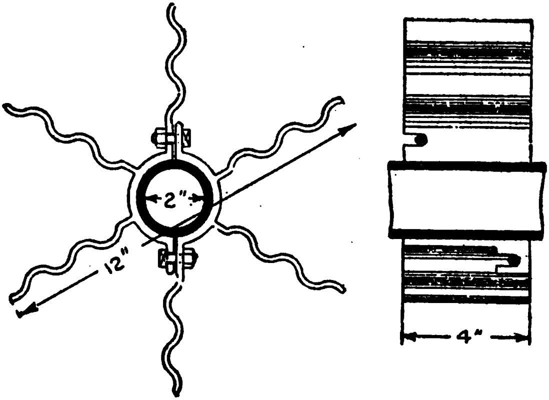
FIG. 5,492.—Vilter small can ice plant; capacities 1,000 to 6,050 lbs. ***Compressor,*** vertical single acting belt driven type with by pass between main suction and discharge stop valves permitting reversal of compressor action so that entire charge of ammonia can be pumped from condenser and stored in the freezing coils, or vice versa, when it is desired to examine or make repairs to either the *h.p.* or *l.p.* side of the plant. ***Oil separator,*** horizontal type connected in discharge line leading from compressor to remove oil from the hot discharge gases before they pass into the condenser. The freeze valve at the bottom of separator is used for draining off any accumulated oil ***Condenser,*** double pipe type attached to side of freezing tank, cooling water entering at the bottom circulates through the inner pipes, while the hot ammonia gas entering at the top, traverses the annular space between the pipes and passes as a liquid to the receiver below. The blow off valve at highest point permits blowing off any non-condensable vapors from condenser. ***Liquid receiver,*** seen below condenser; it is for storing liquid ammonia from condenser. ***Freezing tank and coil:*** the number of cans is such as to permit slow freezing. Coils are in loop form, made from one piece of pipe. A valve is provided to blow air, oil or scale from the coils, or charging the system with liquid anhydrous ammonia. ***Brine agitator,*** is of horizontal type and usually driven by link belt chain from a sprocket on compressor shaft. It circulates the brine to maintain a uniform freezing temperature throughout the tank.

NOTE.—***Anhydrous ammonia.*** *Anhydrous* means *free from air.* Pure anhydrous ammonia is under ordinary atmospheric conditions a colorless gas; this gas may be transformed into a liquid state, just as ordinary air may be transformed into what is popularly known as *liquid air.* The change from the gaseous to the liquid state is accomplished by the application of pressure (average under good operating conditions 130 to 185 pounds gauge). The change from the liquid back to the gaseous state is accomplished by the release of either all or most of the pressure of liquification by means of a pressure reducing valve (under operating conditions average pressure for gasification is 10 to 25 pounds gauge). Anhydrous ammonia, when changing its state from a liquid to a gas, has the inherent property of producing a cooling effect, similar to the cooling effect produced by ice when changing its state from the solid to the liquid state. For every pound of liquid anhydrous ammonia that changes its state from a liquid to a gas, about four times as much cooling effect is obtained as that produced by the melting of one pound of ice. Anhydrous ammonia is usually sold in drums containing 50 or 100 pounds.

The reduction of pressure in passing through the expansion valve causes the liquid ammonia to vaporize, but in order to do so it must be supplied with a certain amount of heat known as its



FIGS. 5,493 and 5,494.—Radiating discs, showing method of attachment to direct expansion coils. These discs are placed upon the pipes to increase the heat conducting surface.



FIGS. 5,495 and 5,496.—Radiating strips attached to freezing coils sometimes used in place of the discs shown in figs. 5,493 and 5,494.

latent heat of vaporization or simply latent heat. This heat is absorbed from the surrounding substances or bodies, thus producing the refrigerating effect as the ammonia is evaporated in the expansion coils. After passing through the expansion coils, the vaporized ammonia returns to the compressor to be recompressed, thus completing the process.

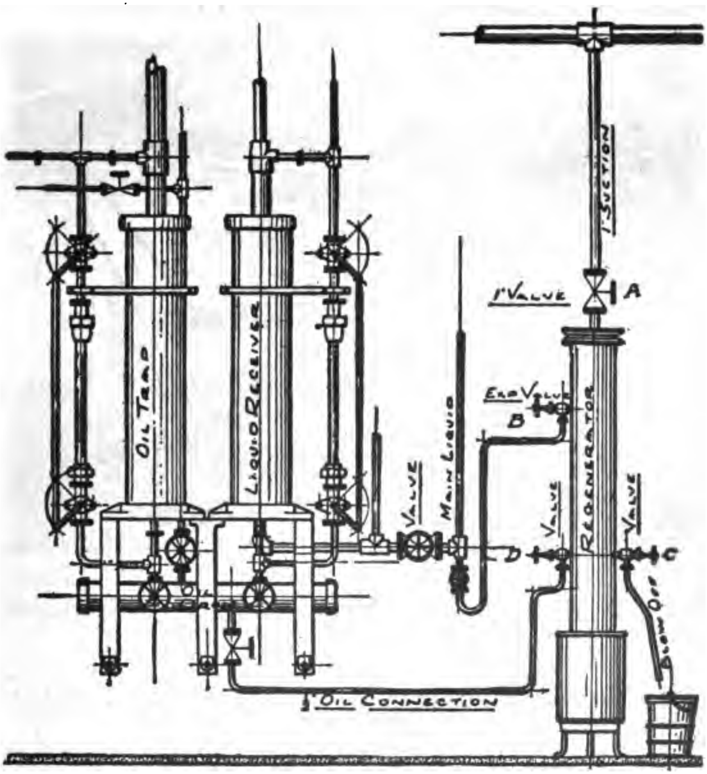


Fig. 5,497.—Regenerator and connections to receiver. The liquid enters the regenerator through the pipe **D** and expansion valve **B**, and the pure vapor is allowed to escape by means of the valve **A**, into the suction of the compressor. When charging the regenerator the valve **A**, is closed, and during the distilling process the valve **B**, is closed. **C**, is a blow off.

Ques. What name is given to this form of compression system, and why?

Ans. It is called the direct expansion method because expansion takes place in pipes placed in direct communication with the substances to be cooled.

Ques. What are the advantages of this method?

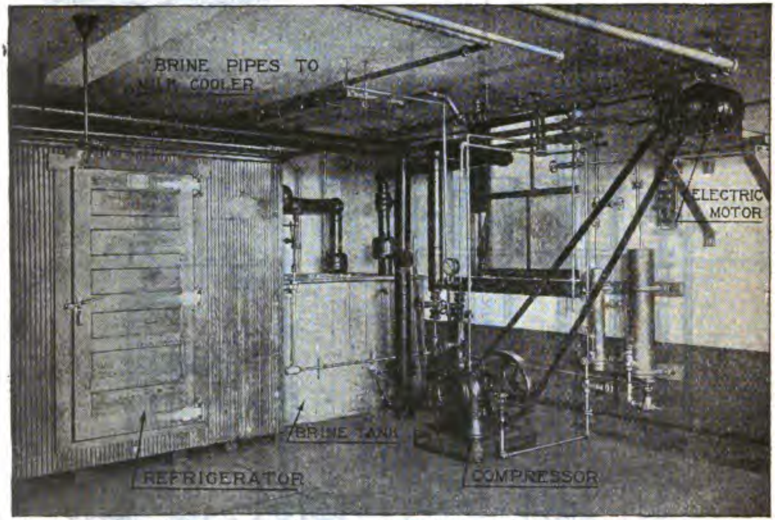


FIG. 5,498.—Brunswick compression system installation adapted to dairy work. *In the plant* the compressor is connected to a combined ice making and brine cooling tank and a storage refrigerator. The low temperature brine is pumped from the tank to the tubular cooler, where the milk is reduced to a temperature of 40 degrees in less than half the time required by the old "cracked ice method."

Ans. Simplicity, economy, ease of operation, and compactness.

Ques. What is the disadvantage of the direct expansion method?

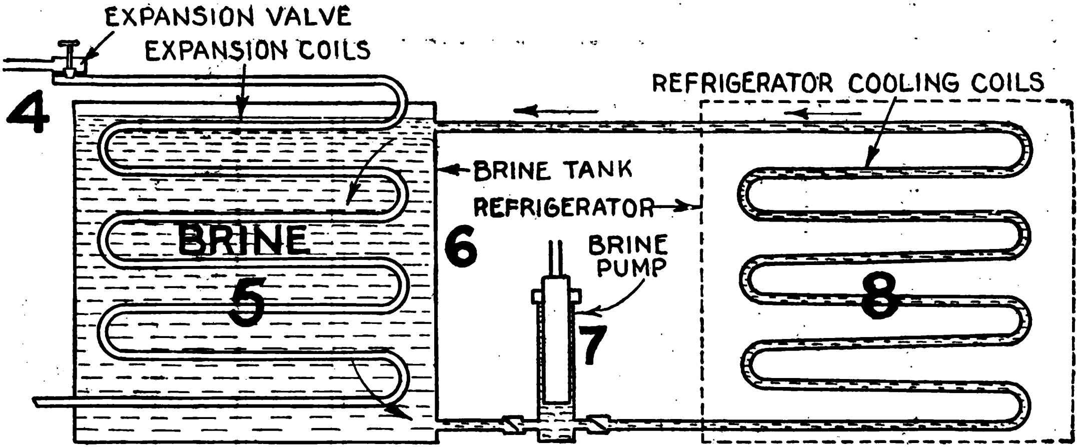


FIG. 5,499.—Elementary **ammonia compression system;** *indirect expansion or brine circulation transmission.* This system consists essentially of the five elements shown in fig. 5,489, and the additional elements; 6, brine tank; 7, brine pump, and 8, refrigerator cooling coils as here shown. ***In this method*** the application of the refrigerating effect is indirect, that is the expansion coils whenever the cold is produced is not in direct communication with the substances to be cooled, the low temperature being transmitted to the space to be cooled or refrigerator by means of brine in circulation.

Ans. It has no reserve capacity, that is, it must operate continuously as long as the refrigerating effect is desired.

Evidently, then, the direct expansion method is not well adapted to plants which are shut down during the night.

Ques. What is the indirect expansion or brine circulating method?

Ans. This consists in the expansion of the ammonia through piping submerged in brine in a tank as shown in fig. 5,500. The brine, cooled to a low temperature by the ammonia in the expansion piping or cooler, is pumped through cooling coils placed in the refrigerator as shown.

Ques. What are the advantages of the brine circulating method?

Ans. Where the plant is designed for operation by day only

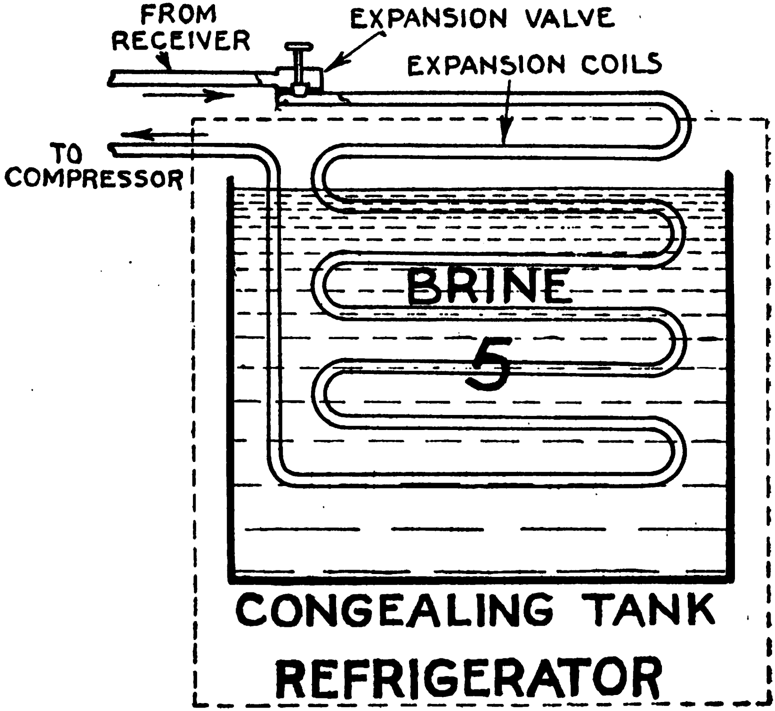


FIG. 5,500.—Elementary ***ammonia compression system;*** *semi-indirect or congealing tank transmission*. As shown the direct expansion piping is located in the refrigerator but is submerged in a tank filled with brine, this heat from the substances in the refrigerator is transmitted to the expansion pipes by the brine. Here there is no forced circulation as in the brine circulating method. While this system gives some reserve capacity the expansion coil and tank occupies more room in the refrigerator than in the direct expansion method.

the brine tank is made sufficiently large to afford storage of cold brine, the temperature being maintained when the compressor is shut down by continuing the circulation with the pump. It is well adapted to large installations, where the various compartments to be cooled are widely scattered.

The reserve capacity of the brine circulation method is of importance in case the compressor be shut down for repairs.

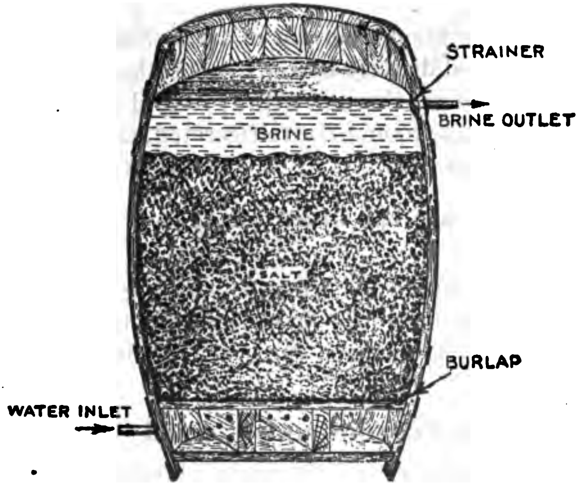


FIG. 5,501.—Method of making brine. Take a water tight barrel and fit a false bottom or wooden grating as shown. A single thickness of burlaps should be stretched across the top of the false bottom and tacked to the sides of barrel. The outlet pipe for the brine should be four or five inches below the top of the barrel, and the water supplied at the bottom from a convenient hose or faucet. The supply pipe should be of about 1¼ inch diameter, and the outlet pipe about 1½ inch inside diameter. *To make brine*, fill the barrel above the false bottom with salt and turn on the water. The salt will dissolve rapidly, and more must be shoveled in on top. The barrel must be kept full of salt, or the brine will not be of full strength. *No stirring is necessary*. Keep skimming off all waste matter rising to the top. The brine outlet should be provided with a strainer of some kind, somewhat as shown in the figure, to prevent chips, etc., running out with the brine. The brine cannot be watched too closely, for it will cause trouble and annoyance if not kept at the right density. There is considerable loss of brine from evaporation and leakage depending upon the location of the brine tanks, and the tightness of the stuffing boxes on the pump rods. Such losses as these are serious at times, and particularly where the engineer omits to test the density of the brine. If brine get too weak it will freeze on the pipes of the expansion coil, thus forming an insulation which obstructs the transfer of heat from the brine to the ammonia within the expansion coil. and the machine will not do its full work.

Ques. Describe the semi-indirect or congealing tank method.

Ans. In this method the expansion coils are placed in the refrigerator or space to be cooled, and instead of being in direct communication with the substances to be cooled, are submerged in congealing tanks filled with brine.

Ques. Describe the cold air method of applying the cold.

Ans. In this system a current of air is chilled by passing over coils of pipe cooled directly by the evaporating refrigerant, or by brine, or by passing it through a spray of cold brine. This chilled air is passed into the room to be refrigerated, and then back to the cooling coils, thus maintaining a continuous circulation.

Ques. What are the disadvantages of the cold air system?

Ans. It is not applicable where any drying of the goods by air currents would be harmful. A serious objection to its adoption is the fire risk—that is, the spreading of fire through the air passages.

Ques. For what conditions is the cold air system suited?

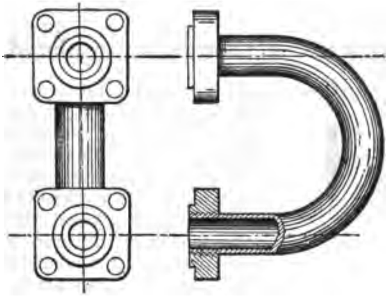
Ans. It is used for such service as chocolate dipping rooms, ice cream hardening, fur storage, etc.

Ques. What is pipe line refrigeration?

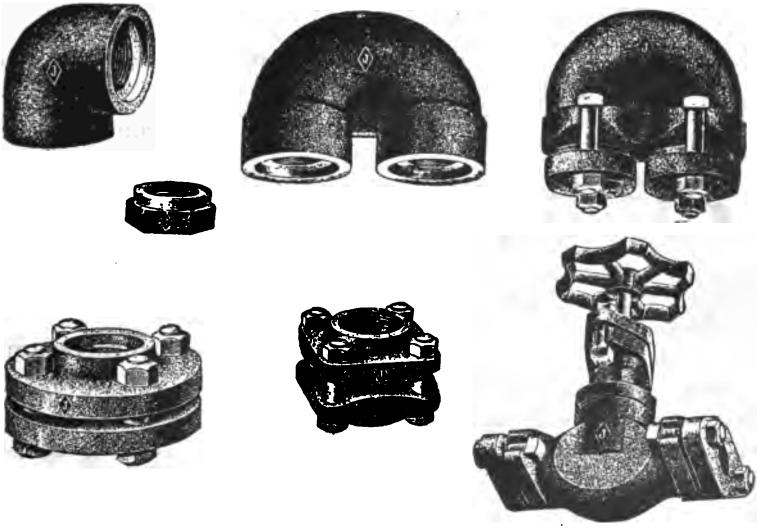
Ans. The production of cold as an equivalent for ice at places remote from the source by means of transmission through wrought iron street mains.

Ques. Describe two systems of pipe line refrigeration in use.

Ans. For short distances circulation of brine is used, the low temperatures being produced at the source; for long distances anhydrous ammonia is transmitted through the pipe and passed through expansion coils at the places to be cooled.



Figs. 5,502 and 5,503.—Solid return bend with flange connection.



Figs. 5,504 to 5,510.—Jarecki cast iron ammonia fittings. Fig. 5,504, elbow with recess; fig. 5,505, jamb nut; fig. 5,506, return bend with recess; fig. 5,507, condenser return bend; fig. 5,508, flange union; fig. 5,509 (malleable) flange union; fig. 5,510, globe valve.

The latter method is in successful operation over lines of several miles in length, and refrigerators along its course are cooled as effectively as in a cold storage warehouse.

Ques. What provision must be made on brine pipe line installations?

Ans. The pipes must be thoroughly insulated.

This is done by putting the pipe in boxes of creosoted plank and filling in with pitch and cork. Among the objections to the brine pipe system are: 1, more or less loss of heat from the brine tank however carefully insulated it may be; 2, it requires considerable power to drive the brine, sometimes a distance of several thousand feet; 3, the brine may also cause in the course of time a rusty and slimy deposit on the interior of the pipes, which makes an insulating coating; 4, a loss of efficiency possibly as high as 25 per cent.; 5, corrosion from electrolysis caused by galvanic action.

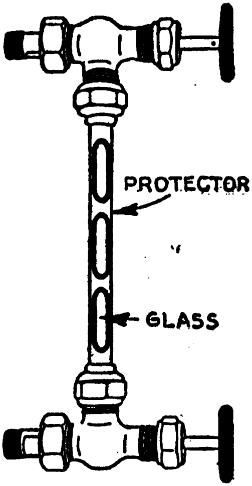


FIG. 5,511.—Ammonia gauge with glass protected by a tube cut out at intervals to show the level of the liquid.

Ques. Name two methods of compressing.

Ans. Dry compression and wet compression.

Ques. What is dry compression?

Ans. Compression in a cylinder cooled by a water jacket.

Ques. What is wet compression?

Ans. In this method, the cylinder is not jacketed, but a certain amount of liquid anhydrous ammonia is allowed to enter the cylinder with each stroke, the cylinder walls being cooled by its evaporation.

Ques. What is the objection to the wet system?

Ans. It is harder on packing, as there are few soft packings that will stand the freezing action of the liquid anhydrous ammonia without becoming hard and causing leaky stuffing boxes.

COMPRESSION SYSTEM PARTS

Compressor.—There are various types of compressor; they may be either vertical or horizontal, and there is much variation in the details of the valves. These differences are due to attempts to reduce clearance and heating. To prevent injury because of the practically zero clearance, a false head is provided with springs to hold it against the cylinder end in

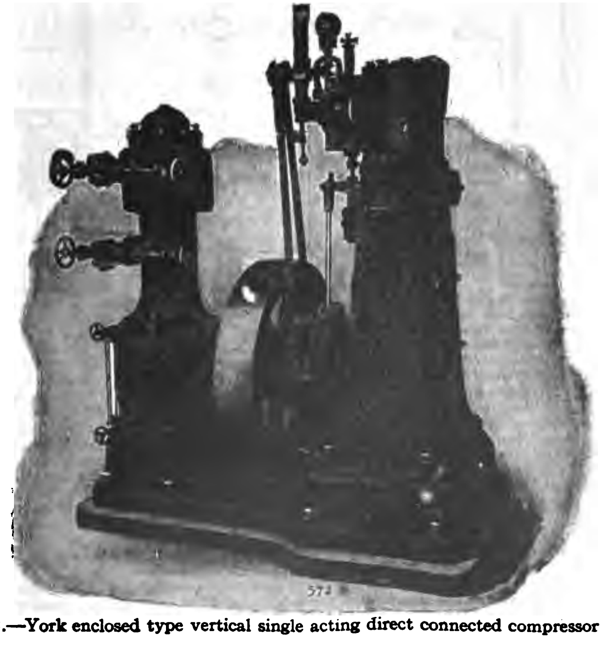


Fig. 5,512.—York enclosed type vertical single acting direct connected compressor.

order that if the piston overtravel because of a loose bearing it will simply raise the head.

On some vertical compressors oil is used in the cylinder to fill the clearance

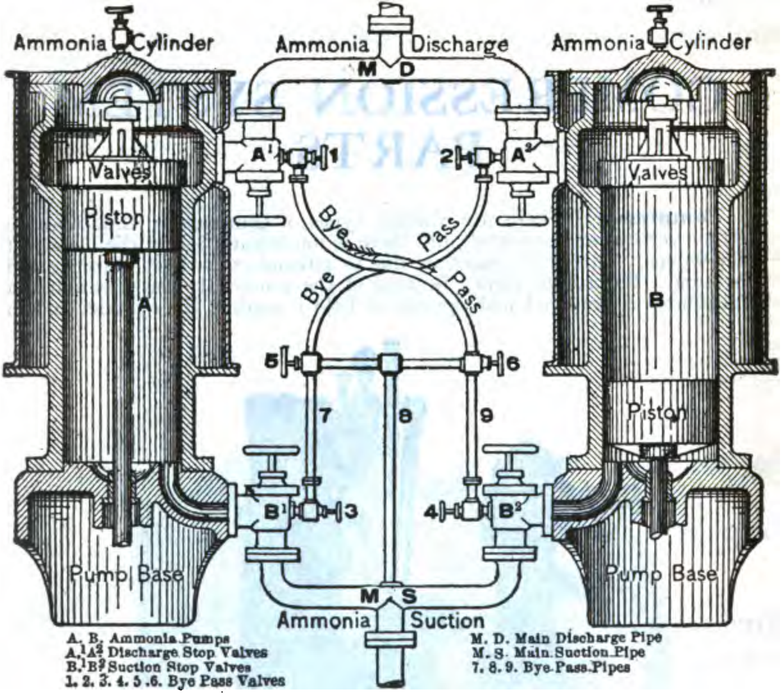
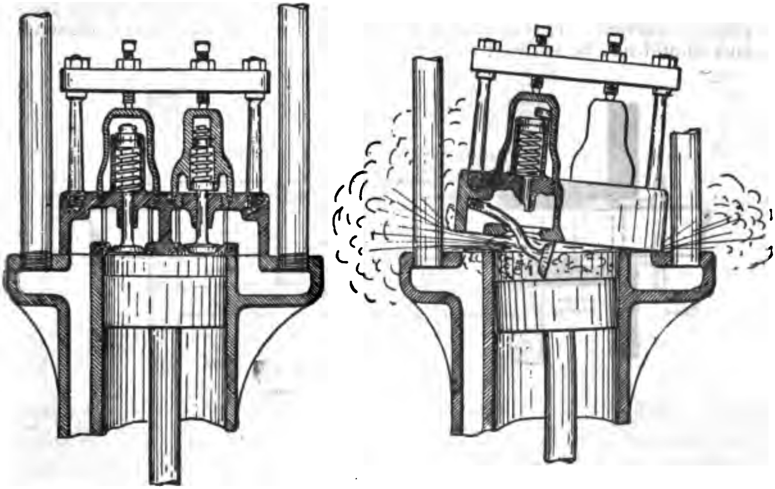


FIG. 5,513.—Single acting Frick compressors, showing by pass system. A, B, compressor cylinders; A^1, A^2, discharge stop valves; B^1, B^2, suction stop valves; 1, 2, 3, 4, 5, 6, by pass valves; M, D, main discharge pipes; M, S, main suction pipes; 7, 8, 9, by pass pipes. ***To exhaust*** gas from compressor B (large machines): All valves closed. Open main discharge stop valve A^1 and by pass valves 2 and 3. Run machine slowly until compressor cylinder is exhausted, then close by pass valve 3 and cylinder head may be removed. After replacing cylinder head the air may be expelled by closing main stop valve A^1 and discharging through purging valve on head of cylinder A. To exhaust gas from compressor A, proceed in same manner, using opposite set of valves. ***To exhaust*** ammonia condenser ***and store*** in evaporating coils or low pressure side: Open main discharge stop valve A^1, by pass valves 1 and 4, thus connecting to suction of cylinder B, and expelling gas by opening by pass valves 2, 5 and 7 into main suction pipe. Run machine slowly. By using opposite set of valves the other cylinder may be used, as one is used to exhaust the gas from the discharge through by pass, while the other expels it through the other portion of by pass into the suction pipe and low pressure side. When the machine is running on regular duty the by pass valves must be kept closed.

space and to absorb the heat of compression, although this method is objectionable in that the oil gets into the condenser and expansion coils, rendering them less efficient in transmitting heat. The engineer should be able to tell whether the compressor valves are working properly by putting his hand on the inlet or outlet pipes.

In operating a compressor, carry as high suction pressure as possible, or such that the boiling point of the ammonia will be about 10° Fahr. below the working temperature.

It is well to have a compressor stuffing box in two parts or double packed, the inner part to be of proper proportion to hold the packing against the loss of ammonia and the outer of only slight depth to retain the lubricating oil within the annular space provided between the two, and through which the rod passes in its travel.



FIGS. 5,514 and 5,515.—Accident to compressor with fixed head, showing necessity of a spring head. *As shown* the suction valve cap and nut have unscrewed, allowing the valve to drop into the cylinder, and, being caught on the return stroke of the piston, has caused piston to force off the head as shown.

In operation, scale and grit from the piping may pass through the valves, and some parts are caught while the valves are closing. The constant hammering of these small particles of metal or sand between valve and seat make both very rough, so that they cannot close tight.

If too rough for grinding, have the valves faced off a little and then grind them to the seat until the surfaces are smooth and without deep spots or holes. See that the valve stems have no shoulders and work free without being too loose in the housing.

The condition of ammonia vapor returning to the compressor is best indicated by a thermometer inserted in a mercury well in the suction line. A table of "properties of saturated ammonia" will show the saturation temperature corresponding to the back pressure.

If the last trace of the liquid ammonia be evaporated before the vapors reach the compressor, there is likely to be considerable superheating, that is, the temperature of the vapor entering the compressor is likely to be several degrees higher than that shown by the tables to correspond to the back pressure carried. This condition results in a considerable loss of efficiency and should not be allowed to continue.

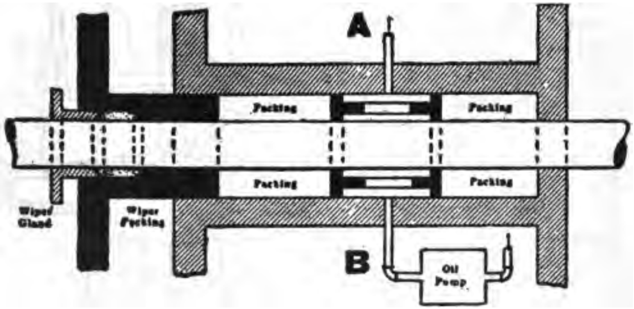


FIG. 5,516.—Stuffing box of compressor cylinder. It is divided into three sections by a separator, spool or lantern, which occupies the middle section of the box. At A, and B, are shown openings to which the oil pipes connect. These openings lead to a cavity surrounding the piston rod, and which is filled with oil. The oil is circulated through this annular cavity by means of a pump, which returns it to a reservoir after circulation. The oil is thus circulated in a continuous cycle. ***In the single acting compressor,*** because of the low pressure on the stuffing box, the leakage of ammonia past the piston rod is easily prevented. There is, however, some pressure upon the packing, and it should, therefore, not be neglected, as the leakage under as low a pressure as 15 pounds is quite serious. ***In a double acting compressor*** the stuffing box is subjected to the high pressure gas, and, therefore, requires more careful attention. However, the manufacturers of modern double acting compressors have improved the stuffing boxes to such an extent that the danger of leakage is but trifling.

Where low temperatures are carried the return gas may be so far below 32 degrees Fahr. that the same rise in temperature that would ordinarily completely change the appearance of the return line if it took place at a higher temperature would not affect the frosted line at all, as far as outward appearances are concerned.

The frosting of the return pipe is an indication that the ammonia gas therein is taking up heat from the surrounding atmosphere, and this heat will have to be disposed of in the condenser coils. If, then, a certain amount of the heat in the returning ammonia gas have its origin in the engine room, where its absorption is manifested by frost in the return line to the compressor, it is evident that the frosting of the line costs energy to drive the compressor and that this energy costs coal, labor, and, finally, money. The return lines to compressors should be effectively insulated to reduce this loss.

To reduce the compression temperature in a dry compressor it is a common practice to "carry the frost back" to the inlet valve of the compressor, or to allow it to extend slightly beyond this.* The gas in such a case is at a fairly low temperature at the start of the compression stroke, and will, therefore, not heat.

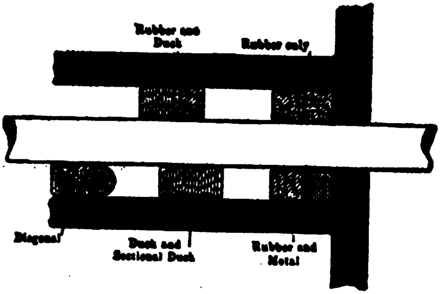


FIG. 5,517.—Various approved packings used for ammonia; any of them may be employed independently, or two or more used together. It is difficult to recommend any special form of packing. Some engineers will pack with pure rubber rings entirely. Others will use rubber and ordinary duck expansion packing alternately. Still others use an expansion ring and a sectional ring so as to secure a quick adjustment. A great many use a diagonal packing with excellent results. A skillful engineer will use any of these packings with success. The great objection to many of them is that the loose fibers, which become detached by the action of the rod or of the oil, manage to get into the oil wells or small pipes through which the oil passes, and clogging them up, may prevent the flow of oil and consequent lubrication.

The condition generally accepted as most efficient is to carry the frost back to the inlet valve without allowing it to extend beyond the same, nor to fall back to any great extent.

If the frost be carried back beyond the inlet valve, the indications are that the vapor contains a considerable amount of liquid which is still under the process of vaporization. The percentage of this liquid, generally consisting of minute drops, may be so great that its vaporization will extend well into the compression stroke, thus having the same effect as if it were

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* NOTE.—If the return gas from the expansion coils be allowed to reach the compressor at or slightly below freezing temperature, a coating of frost forms on the pipe, the phenomenon being called "carrying the frost back to the compressor."

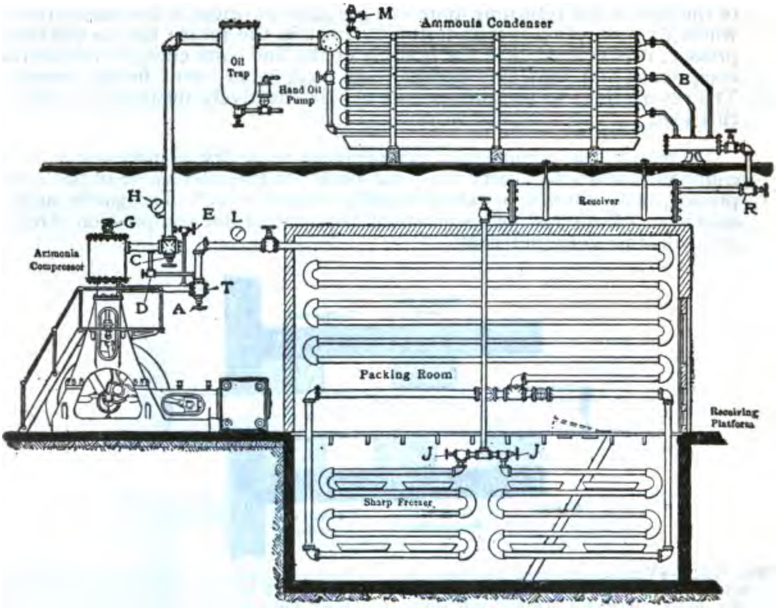


FIG. 5,518.—Ammonia compression system in fish freezer illustrating method of pumping out for repairs. Only one single acting compressor is shown. To take off cylinder head, if something be broken inside and it be impossible to have the machine turn over, the valves A, C, and E, should be shut, and valve D, opened. This will put the discharge side of the cylinder in communication with the low side, and the pressure in the top of the cylinder will be equalized with that in the low side. Then close the by pass valve D, and open the cylinder purge valve G, which will allow the ammonia remaining in the cylinder to escape to the atmosphere. As it is only at the pressure of the low side it will take but a few seconds to blow off. When the compressor is in a poorly ventilated room, the purge valve G, should be connected to a piece of hose, the other end being held under the surface of the water in the cylinder jackets. The hose should not be held under the water too long or all the ammonia will be absorbed by the water; this will leave a vacuum in the compressor cylinder, and the water will be forced into the cylinder. It is quite a job to sponge out this water in the pipes and ports. If the compressor can be turned over, the quickest way to pump all the ammonia out of the compressor that is doing the pumping is to leave the valves as before; A, C, and E, closed and D, open. Then by giving the machine a few turns all the ammonia will be pumped out of the bottom of the cylinder and the suction pipe up to the stop valve A. Valve D, is then closed and the purge valve G, opened. By using this method only about one-third as much ammonia is wasted as when the whole cylinderful is blown out, as there is only the small amount of gas above the discharge valve to be blown out. When it is desired to open up the low side, the expansion valves J, J, are closed and the ammonia pumped up to the high side by the compressor in regular operation. To pump an air pressure on the low side with the ammonia in the high side, valves A, C, and E, are closed and valve D, is open. The side bonnet T, or other flanges are opened and the compressor pumps the air through T, into the cylinder, and thence through by pass D, into the low side. To pump the air out of the low side with the ammonia stored in the high side, valves C, D, and E, are closed and valves A, and G, are opened. The pumping out of the high pressure side of the system, including the injected, namely, taking up part of the heat of compression for its vaporization. The action of the compressor, therefore, approaches that of a wet compressor.

If the frost be carried completely over the cylinder so that the water jacket has a layer of ice on its surface, it can be assumed that a portion of liquid ammonia is injected on each stroke.

Ammonia Condenser.—Several types of condenser are in use: 1, atmospheric; 2, double pipe; and 3, submerged. The form most desirable depends upon the proposed location and size.

If it can be placed on the roof or in an open room, the open air condenser is preferred on account of its more economical use of water, and it is easy of access in case of repairs.

The double pipe condenser is favored where water is to be used over again for some other purpose and where the open air style cannot be used on account of building construction. This style is made with one pipe inside of another. The water being on the inside of the inner pipe and the ammonia in the annular space between the pipes.

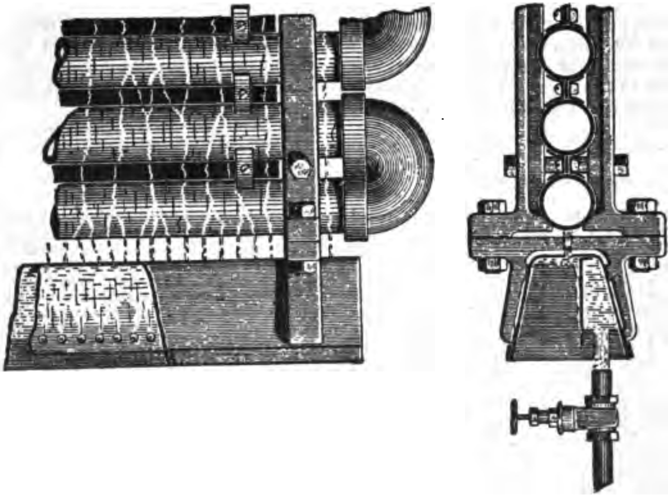
FIG. 5.519—*Text continued.*

condensers, the pressure tank and the liquid tank, is a slightly more complicated affair than that of the low pressure side. It is accomplished by means of a pair of by passes between the main suction and the main discharge lines, as shown. By means of these by passes the action of the compressor can be reversed, so that the suction becomes the discharge and the discharge the suction line. Ordinarily, the by pass valves D, and E, are kept closed, and the main line valves A, and C, open, so that the gas returning to the machine through the main suction line would pass through the main suction valve A, through the compressor and out the main discharge line through main discharge valve C. First open the expansion valves J, J, wide open; this will let all the liquid ammonia run into the low pressure coils. While the pressure is equalizing in the high and low sides the machine valves can be adjusted. All the cylinder stop valves, as A, and C, are closed. The by pass valves D, and E, are opened. Reference to the sketch shows that there is a clear passage from the discharge side through by pass E, into the bottom of the cylinder, and when the machine is in operation, the gas is discharged through by pass D, into the low or suction side. This reverses the compressor. The reason for equalizing with the expansion valves J, J, instead of through the by passes, is to get all the liquid ammonia into the low side before starting to pump out. When the pressure is equal on the gauges H, and L, shut all the expansion valves J, J, and start the compressor. It will take all the ammonia out of the high side and discharge it through by pass D, into the low side. The cold parts of the low side, such as the ice on the coils and the air in the freezers, will act as a condenser, and the ammonia will liquefy and be carried away. If there be not an overcharge in the plant, and no foul gas, the pressure in the low side, when it contains the entire charge of ammonia, will not rise above that pressure due to the temperature of the coldest part of the low side. ***In pumping out*** the high pressure or discharge side, the machine must be run very slowly, in order to give the gas time to pass through the small by pass lines. In this operation valves D, and E, are open and valves A, and C, are closed, so that the suction is cut off at A, but continues through valve E, to the former discharge line and the discharge cut off at C, continues through valve D, to the former suction line. When the pressure on the high pressure gauge is down around 25 inches of vacuum the machine can be stopped and by pass valve D, closed, to keep the pressure of the low side away from the cylinder. Then close valve E, and give the discharge stop valve C, a turn open. When the small amount of gas at back pressure that is above the discharge valves has run back into the vacuum of the high side, the stop valve C, is closed and a vacuum is formed on the whole of the compressor cylinders, and they can be opened up without any fear of escaping ammonia. Next to the compressors, the high side has to be opened up more frequently than the other parts.

The round coil submerged condenser is used with small machines, or where the condenser must be placed in a closed room.

The economy with which any plant may be operated depends to a large extent upon the condenser, and no harm is done by having it a little larger than is absolutely necessary. Care must be taken to have the water flowing over a condenser so distributed that all the radiating surface possible will be covered, because a much higher efficiency is thus obtained.

A careful watch for leaks should be maintained, the water should flow evenly, covering the pipes equally, and in the use of double pipe or shell condensers it is well to thoroughly flush the water pipes occasionally to remove any coating or obstruction that may form in them.



Figs. 5,520 and 5,521.—Condenser coils with trough and strips between pipes to prevent splattering of the cooling water.

Common practice among the trade has established a rule, that is, to allow 24 square feet of condensing surface per ton of refrigerating capacity, when operating with a cooling water temperature of from 58° to 70° Fahr., which is equivalent to approximately 38 lineal feet of 2 inch pipe per ton of duty.

The amount of water required per minute per ton of refrigeration for atmospheric condensers is approximately ½ gallon to 1½ gallons for temperatures ranging from 50° to 80° Fahr. when the water leaves the condenser at 95°.

The engineer can tell when it is necessary to increase the ammonia charge by watching the condenser pressure: a reduction of 10 or 15 pounds, while the suction and condenser exit pressure remained the same, would show the necessity for making up a leakage loss.

The lower the pressure and temperature in the condenser coils and the higher the temperature and pressure in the expanding coils (the back pressure), the more efficient is the working of the machine.

Although it is not generally considered the best practice, the lower pipes of a condenser are sometimes used to store the liquid ammonia, thus eliminating the ammonia receiver from the system the ammonia being drawn directly from the condenser coils and passed through the expansion valves.

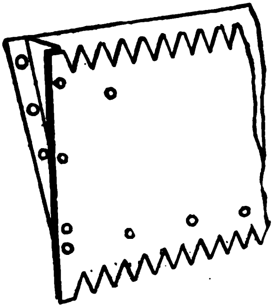
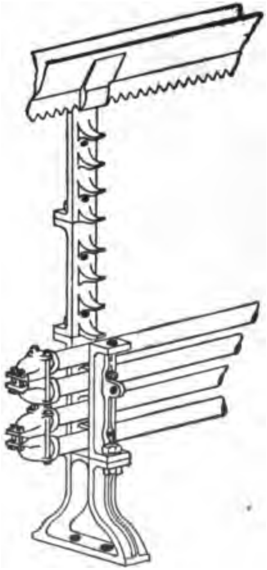


Fig. 5,522.—Atmospheric ammonia condenser trough. The saw tooth edge of the metal distributes the water evenly along the pipe and prevents splattering.

Fig. 5,523.—Atmospheric ammonia condenser pipe stand with dripping trough.



Oil being a poor conductor of heat, special care should be taken to prevent it entering the condenser.

In setting up a condenser for ammonia the branch pipes from the discharge to the compressor, as well as from the liquid return pipe, should have valves placed in them. In this case, if a defect occur in any stack of coil in the condenser, it is an easy matter and takes but little time to pump down and cut out the defective stack, and then go on with the operation of the plant while repairs are being made.

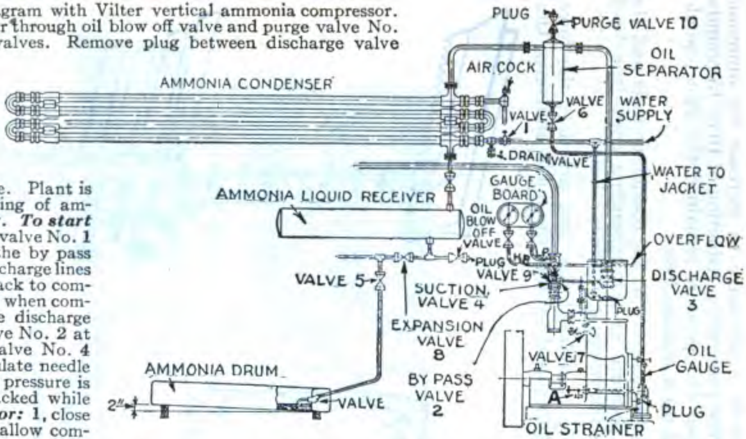


FIG. 5,524.—Compression system diagram with Vilter vertical ammonia compressor. ***To free system of air:*** Blow off air through oil blow off valve and purge valve No. 10. After air is out close these valves. Remove plug between discharge valve No. 3 and compressor. Close discharge valve No. 3, suction valve No. 4, and by pass valve No. 2. Open by pass valve No. 9. Start compressor, and operate until a good vacuum is registered on gauges. Stop compressor, close valve No. 9 and expansion needle valve No. 8. Screw plug into place. Plant is now ready for starting and charging of ammonia. Follow directions carefully. ***To start compressor:*** 1, open water supply valve No. 1 on ammonia condenser; 2, open the by pass valve No. 2 between suction and discharge lines on compressor; 3, throw fly wheel back to compression; 4, turn on the power, and when compressor is running, open the angle discharge valve No. 3, and close by pass valve No. 2 at the same time; 5, open suction valve No. 4 gradually, and pump down; 6, regulate needle expansion valve No. 8 until proper pressure is obtained; 7, keep valve No. 7 cracked while running only. ***To stop compressor:*** 1, close needle expansion valve No. 8 and allow compressor to run until suction gauge reads 0; 2, close valve No. 7; 3, close suction valve No. 4 and let compressor turn over several revolutions so that cylinder and crank case will be free of pressure; 4, turn off power; 5, when machine stops close discharge valve No. 3; 6, close water supply valve No. 1. ***Needle expansion valve:*** this valve controls the suction pressure, and is very sensitive. For this reason care should be taken not to open it too widely, which would allow ammonia liquid to return to the compressor through the suction pipe. It is quite usual for the frost to come back to the compressor cylinder, but the discharge pipe should not be cold. If this condition be found, close the expansion valve slightly so that the discharge pipe gets hot, or so that you can touch same with your hand. In case the brine does not get cold enough then throttle expansion valve. ***To charge:*** close expansion valve No. 8, and connect ammonia drum to valve No. 5 by means of the ½″ pipe. Then open valve No. 5 wide, and crack valve on ammonia drum, and pump until the discharge gauge indicates a pressure corresponding to the temperature of the water on the condenser. (With the usual amount of water at 60° the pressure will be about 150 pounds; with 65° water, 160 pounds; 70° water, 170 pounds; 75° water, 180 pounds; and 80° water, 190 pounds.) After this close ammonia drum valve and charging valve No. 5, and regulate the needle expansion valve No. 8. When the machine has been running for some time, and no frost comes back to the suction scale trap, there is not sufficient ammonia in the system, and the charging operation will have to be repeated. ***Oil:*** the glass gauge should show about 3″ of oil in the crank case. When the oil starts going down too far then open the valve No. 6 on bottom of the oil separator slightly, place your hand on the drain pipe near the valve No. 6 until the pipe gets cold, which indicates that the ammonia is appearing. ***To add oil:*** close suction valve No. 4, and keeping the valves Nos. 3 and 7 open, and 2 and 9 closed, run compressor until the low pressure gauge shows 0 pounds. Then stop compressor, close the discharge valve No. 3, screw bent pipe into valve A, let same extend into a pail of oil fully submerged, and crack valve A, and let oil syphon into crank case, taking care, however, to have pipe submerged at all times when valve A is cracked. ***To purge system:*** stop machine

FIG. 5,524.—*Text continued.* **for several hours, fill a pail with water,** screw into purge valve No. 10 a pipe bend or nipple with rubber hose attached, submerge end in water, then open purge valve slightly. While bubbles continue to come, the foul gas is still in the system. When ammonia appears, there will be a cracking noise, and when this occurs, shut off the purge valve No. 10.

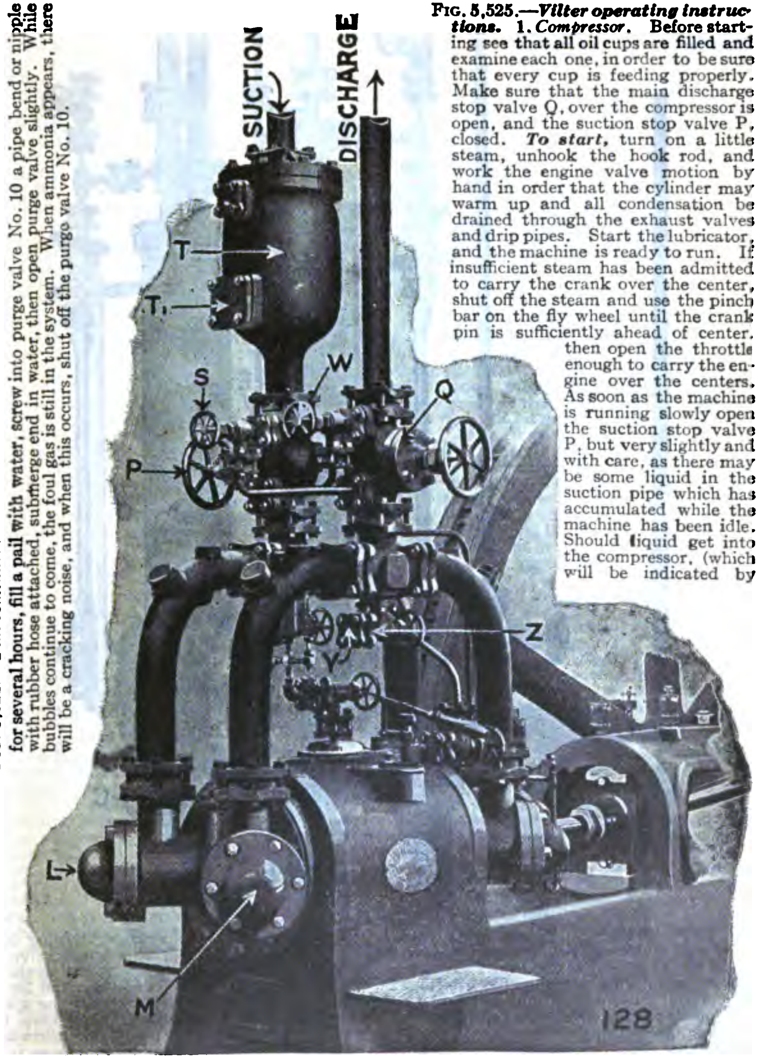


FIG. 5,525.—*Vilter operating instructions.* 1. *Compressor.* Before starting see that all oil cups are filled and examine each one, in order to be sure that every cup is feeding properly. Make sure that the main discharge stop valve Q, over the compressor is open, and the suction stop valve P, closed. ***To start,*** turn on a little steam, unhook the hook rod, and work the engine valve motion by hand in order that the cylinder may warm up and all condensation be drained through the exhaust valves and drip pipes. Start the lubricator, and the machine is ready to run. If insufficient steam has been admitted to carry the crank over the center, shut off the steam and use the pinch bar on the fly wheel until the crank pin is sufficiently ahead of center, then open the throttle enough to carry the engine over the centers. As soon as the machine is running slowly open the suction stop valve P, but very slightly and with care, as there may be some liquid in the suction pipe which has accumulated while the machine has been idle. Should liquid get into the compressor, (which will be indicated by

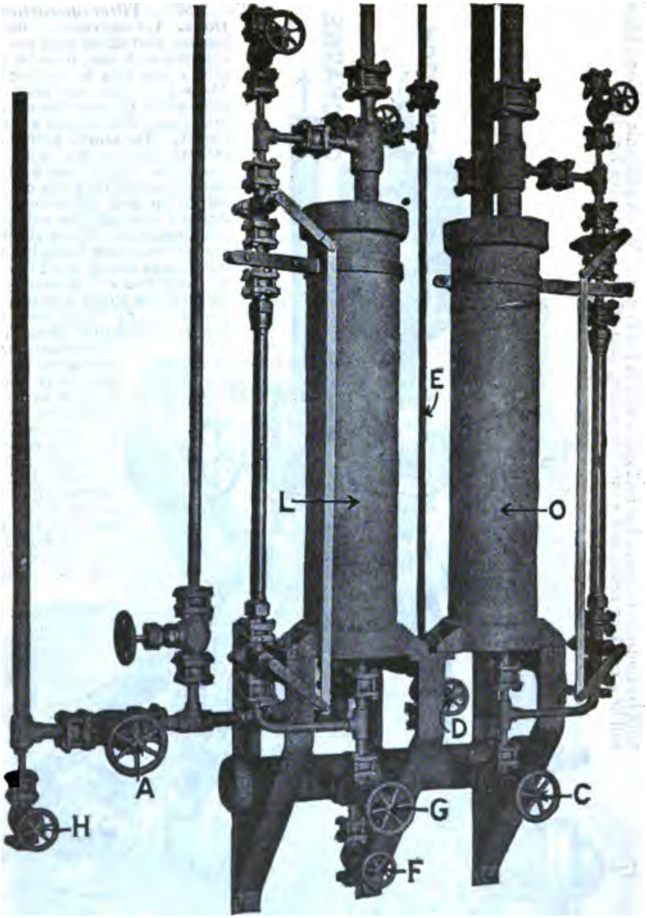


FIG. 5,526.—***Vilter operating instructions.*** 2. *Oil trap and liquid receiver*, showing connections. ***To shut down compressor*** (figs. 5,525 and 5,526), close main liquid valve A, and run the machine until the suction pressure gauge shows about 5 pounds back pressure in order to bring the ammonia gas from the expansion coils into the condenser and liquid receiver. Should the discharge become too warm while running at speed, decrease the speed as much as may be necessary. After the pressure is down to the desired point, close the engine throttle, and when the machine stops running, close suction valve P, ***and afterwards*** discharge valve Q. ***To drain oil trap,*** open valve C, on oil trap O, and leave it open from

FIG. 5,525.—*Text continued.*

a pounding noise), slow down the engine quickly and run it very slowly until the liquid shall have left the compressor and the pounding ceases. This operation will be unnecessary if the suction stop valve is opened very carefully. When the suction valve P, is wide open pump out the system to about 5 or 10 pounds suction pressure, then open the throttle valve and allow the machine to run to speed. Now open the main liquid valve A, from the receiver (fig. 5,526), and when the liquid is up to the feed cocks regulate these, if necessary, to give the proper back pressure, which may be indicated anywhere between 15 and 25 pounds on the suction pressure gauge, depending more or less upon the freezing back to the compressor. Judgment should be exercised in regulating the back pressure. It should be so regulated that the discharge pipe from the compressor will be warm, but not hot enough to burn the hands. When running warm, the compressor works to better advantage and the packing will give much better service than when running cold. It will be found that oil will not work from the stuffing box into the compressor as freely when running warm, and also that the oil will separate in the oil trap O, much more rapidly than when running cold, as the gas will not liquify and settle in the oil trap, where it can not perform its functions. Excess oil in the system is a condition to be particularly avoided.

FIG. 5,526.—*Text continued.*

20 to 30 minutes, then close it. Open valve D, slightly, using it practically as a feed cock. Pipe E, which connects with the main suction pipe, will become frosted, and as soon as it loses this frost will indicate that the ammonia has left the horizontal oil drum under the oil trap and receiver. Close valve D, and allow about 20 minutes for the oil to settle. Then open valve F, and drain the oil into a bucket under suction pressure. It is well to do this when pumping out, as at that time there will be less pressure on the horizontal oil drum, and consequently less waste of ammonia. The oil drawn from the oil drum may be filtered and used again. ***To drain oil from liquid receiver*** (fig. 5,526), oil may also accumulate in the lower end of the liquid receiver L. This oil can be drained into the horizontal oil drum by opening valve G. Leave this open from 20 to 30 minutes, then close it, and again feed the ammonia into the main suction pipe, as directed before, by opening valve D, slightly and freezing through pipe E. The presence of oil in the liquid receiver will be indicated by its appearance in the gauge glass, when gauge cocks are opened, and upon such appearance should be drained from receiver. ***To charge ammonia,*** block up the back end of the drum of liquid ammonia so that the liquid will drain toward the front or valve end of the drum. The cock on the drum must be right side up. Connect the charging pipe to the drum and to the charging valve H, on the liquid line next to the receiver. Close the main liquid valve A, and pump the suction pressure down until the low pressure gauge indicates zero (0°). Then open valve H, wide and regulate the cock on the ammonia drum to operate at about 15 to 20 pounds suction pressure. Keep the machine running until a vacuum shows on the low pressure gauge. The compressor discharge pipe will become hot by running at speed, so the machine must be slowed down until a vacuum is shown, the vacuum giving assurance that all of the liquid in the drum has evaporated. To facilitate removing the last of the liquid from the drum, warm the latter with a blow torch or hot water. Keep the machine running slowly until all the frost has thawed from valve H. To charge another drum, first close valve H, then the cock on the ammonia drum. Break the joints on the charging pipe very carefully, as some ammonia may remain in this pipe. Attach the new drum, open valve H, and the valve on the drum, and proceed as before. After all drums have been charged, valve H, closed, and the last drum disconnected, open valve A, speed up the machine and you will again be running on the system. During the charging process allow the water to run as freely over the condenser as when running regularly. Always weigh ammonia cylinders before and after charging, and see that the weights correspond with those on the tags attached to the drums. ***Gauge glasses.*** The upper and lower gauge cocks—on both oil trap O, and liquid receiver L, should always be shut off, and should be opened only when the liquid or oil level in either reservoir is to be ascertained. The receiver gauge glass should indicate *at least* one foot of liquid in the receiver to give assurance that the system is working with a full charge of ammonia. ***Scale trap.*** It is impossible to manufacture pipe without scale and no amount of hammering or mechanical cleaning will remove all of it from the inside surfaces. In the course of time this scale frees itself and works its way through the pipes towards the compressor. To prevent the scale from passing into the compressor cylinder, a scale trap T, is placed in the main suction line, which catches and retains all scale or dirt passing through the suction pipe. After the machine has been in operation for some time, the scale trap should be opened up and the scale removed. To do this pump out the compressor as explained above and remove hand hole cover T_1, after which the dirt caught in the screen may be scraped out. After cleaning thoroughly, replace the hand hole cover T_1. The scale trap should be examined and cleaned out at least once every season.

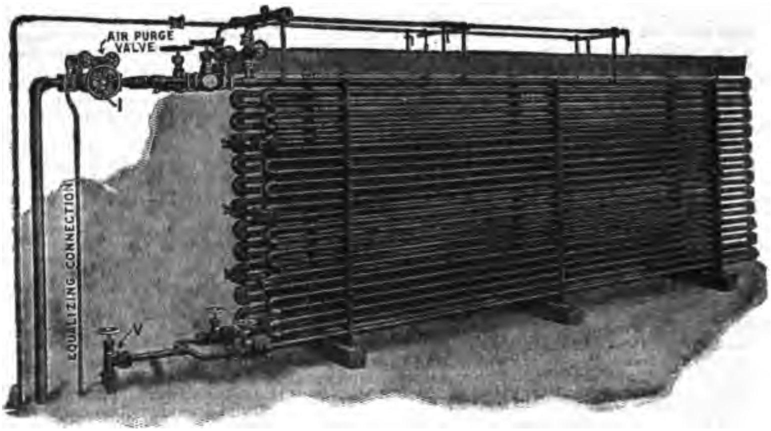
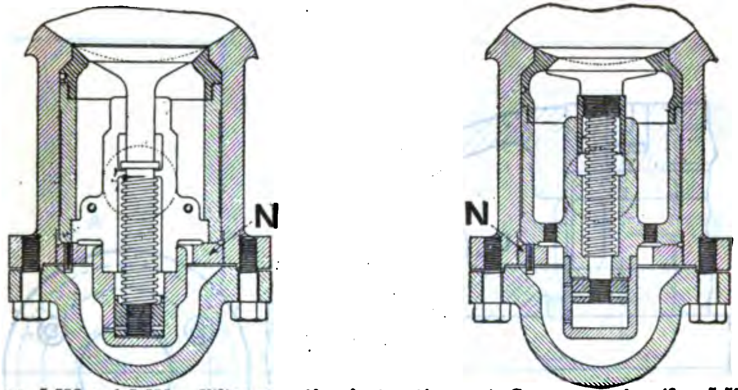


FIG. 5,527 ***Vilter operating instructions.*** 3. *Standard two coil atmospheric ammonia condenser.* ***When charging ammonia,*** or opening a valve in the compressor, air will naturally get into the system. An accumulation of this air will cause high condensing pressure, and the air should therefore be removed as soon as possible. If the high pressure gauge normally register about 150 pounds, and this pressure should rise to 160 or 170 pounds without apparent cause, the indications are that air is present. ***To purge*** this air from the system, remove the blank flange on the air blow off valve connected to the side outlet valve I, at the top of the condenser. Attach a piece of pipe to the blow-off valve and lead it down into a bucket filled with water. Shut down the machine for at least half an hour, keeping the water running freely over the ammonia condenser to liquify the ammonia gas in the condenser and allow the air to rise. Open air blow off valve slowly, allowing the air to blow into the water in the bucket. As long as air alone is escaping, the air bubles coming to the surface of the water will indicate the fact, but as soon as ammonia begins to escape a crackling sound will be heard and the purge valve should be closed. Repeat the operation until all the air is out of the system. ***To pump out*** (figs. 5,525 and 5,527). First shut down the machine and close valve V, at the bottom of the condenser. Then close suction stop valve P, and discharge stop valve Q, on compressor connections, and open the small by pass valves S and W. This will reverse the action of the main suction and discharge pipes and the expansion coils will serve temporarily as a condenser. After all these valves have been set as directed, start up the machine and ***run it very slowly***, as the compressor must discharge through the small by pass connection. ***Slow speed is absolutely necessary*** and the machine should not be run faster than the speed required to carry the motion past the centers. Continue to run until a vacuum is shown by the high pressure gauge, which indicates that the condenser is properly pumped out, then shut down the machine. If any of the joints on the condenser shall have been opened, the entire coil will be filled with air that must be pumped out before regular operation is resumed. After the joints are again closed on the condenser, close valve S, then remove blank flange Y, and run a pipe or hose connection from valve Z, to the open air. Open valve Z, and the discharge will go out through this connection. Run the machine slowly until a vacuum again shows on the high pressure gauge. The condenser will then be free from air. Now shut down the machine, close valve Z, replace blank flange Y, close valve W, and open valve Q, and valve V, at the bottom of condenser, and the machine is again ready to go through its regular course of operation. The suction valve P, ***must be opened slowly***, as previously directed.



FIGS. 5,528 and 5,529.—***Vilter operating instructions.* 4. *Compressor valves*** **(figs. 5,525, 5,526 and 5,527).** ***To remove a valve,*** **close suction valve P, and allow the compressor to make eight or ten revolutions, then stop the machine. Close discharge valve Q, remove blank flange Y, and make a connection to the open air as directed before. Open valve Z, to allow the gas that is in the compressor to escape. Remove valve cap L, or M, take out the set screw in valve nut N, unscrew the valve nut and the entire valve may be removed for inspection. After a machine has been in operation for some time, it is advisable to remove and examine all of the compressor valves, to make sure that they are operating properly and are in good working order. Always bear in mind that the condition of the compressor valves has a direct influence on the coal burned and the work done. They should be carefully inspected *at least* once every season. If the seating surfaces should become cut or pitted, they should be refaced in a lathe and reground, in order to insure absolutely tight valves.**

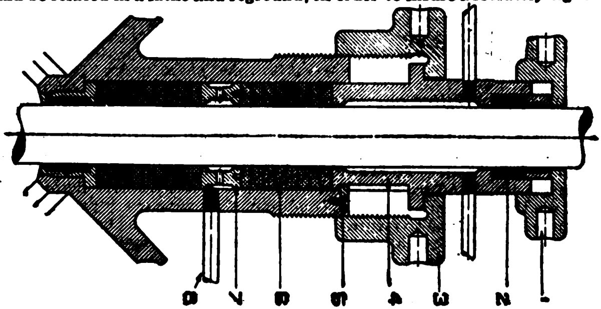
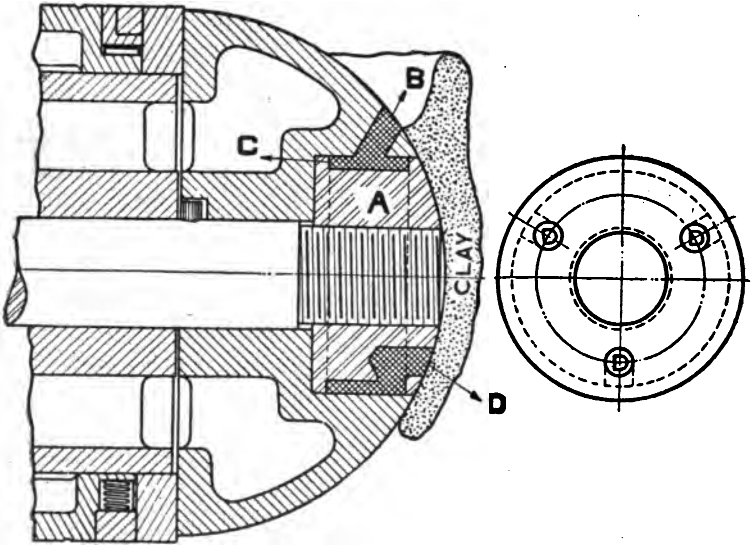


FIG. 5,530.—***Vilter operating instructions.* 4. *Stuffing box. To pack stuffing box,*** **proceed with the pumping out of the compressor in the same manner as directed for the removal of the valves. Screw off the stuffing box nut No. 1, slide it forward on the rod and remove packing No. 2, then unscrew stuffing box nut No. 3 and take out key No. 5. The oil sleeve No. 4 can now be withdrawn from the stuffing box and packing No. 6 removed. Before repacking be sure that all of the old packing has been removed from the stuffing boxes. When putting the new packing in place, see that the lantern No. 7 is in the same relative position to the gas outlet pipe No. 8 as shown in the cut, thus allowing for future tightening of the packing without liability of covering the end of the pipe. Location of the lantern as shown will assure the return of any escaping gas to the main suction pipe through pressure release connection No. 8 and will protect the outer course of packing from any pressure higher than that of the low pressure side of the system.**



FIGS. 5,531 and 5,532.—***Vilter operating instructions.*** 5. *Compressor piston.* ***To open compressor,*** pump out as directed for removing the valves. Disconnect the suction and discharge pipes from the back head, slack up the bolts on the front head connections, then brace up the pipe connections above the compressor, remove the nuts from the back head studs, and pry off the head. ***To examine piston rings,*** remove the round follower nut and follower, then the bull and packing rings will be easily removable. Before replacing rings and springs see that they are in perfect condition, then wipe every part thoroughly with a clean rag (do not use waste) to insure that no dirt or lint remains between any of the parts and prevents contact. When all replacements are properly made, lock the follower nut. Drill out the babbitt filling at B, and D, applying the follower nut wrench to holes D, and turning the nut off the rod and the follower and all bull and packing rings will be easily removable. ***To adjust piston clearance,*** remove a compressor valve from each head (front and back). Insert a strip of sheet lead through the valve opening at one end of the compressor and hold it so that an end of the strip may be compressed between the piston and cylinder head. Turn the machine over by hand, and the compression of the lead will show the clearance. Repeat the operation at the other end of the cylinder to ascertain the opposite clearance. Use nothing harder than lead for the purpose. In adjusting clearance, allow the least at the front head, as the warming up of the piston rod will naturally expand it and reduce the clearance at the back head. ***To replace and lock the piston follower nut.*** Before replacing the follower nut, it is important that the babbit in groove C, is entirely removed, to allow for refilling. To replace the follower nut A, screw it down securely with the follower nut wrench. Then form some clay as shown so as to cover the holes D, and form a cup around hole B. Pour melted

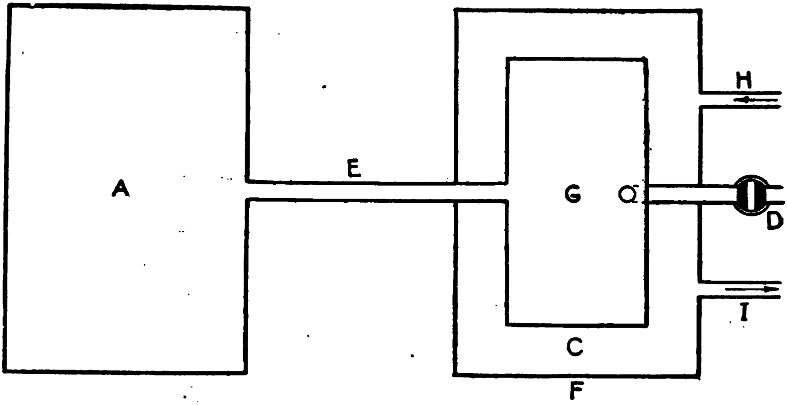


FIG. 5,533. **Diagram illustrating general principle of the ammonia absorption system.** In the figure two vessels, A and G, of proper strength to resist internal pressures of 10 to 15 atmospheres (140 to 220 lbs. per sq. in.), are connected at their tops by a pipe, E. The smaller vessel G, is enclosed within a jacket F, through which and around G, cold water is circulated, entering at H, and leaving at I. The larger vessel A, is partially filled with a strong solution of aqua ammonia and heat is applied as by a fire underneath the vessel A. As the ammonia warms, ammonia gas is driven off and fills G, through the pipe E, air being allowed to escape from the system through a suitable opening in the bottom of G. When ammonia gas begins to issue strongly from this opening, the escape is closed by a cock D, provided for the purpose. Since the volume of gas in solution in the liquor in A, is many times that of the water itself, the continued application of heat drives off such quantities of the gas as to create a constantly increasing pressure in the system. Just as in the case of water, ammonia has for every pressure a corresponding temperature of boiling and of liquefaction, at which temperature ammonia gas will liquefy if heat be abstracted from it, and ammonia liquid will gasify if heat be added to it. If the cooling water have a temperature of 60° F., and maintain the vessel G, and its contents at a temperature of, say, 65° F., it is evident that when the pressure of the gas within G, reaches about 103.33 lbs. per sq. in. by gauge (118.03 lbs. absolute), the further expulsion of gas from the liquor in A, causes a corresponding liquefaction of ammonia in G, and by continuation of the process an accumulation of liquid ammonia results in G, until all the gas has been driven off from the water in A, the pressure remaining constant during the process and the latent heat of liquefaction being carried away by the cooling water flowing out at I. When the distillation of ammonia into G, is completed, the process may be reversed by cooling A. This enables the water in A, to absorb and dissolve the gas in contact with it, creating an immediate flow of gas from G, and causing a reduction of pressure in the system. This decrease of pressure lowers the boiling temperature of the liquid ammonia in G, and consequently it at once starts to gasify. Now as, in liquefying, the ammonia yielded up its latent heat to the cooling water in C, so, in gasifying, heat must be abstracted by the ammonia from its surroundings. Hence, if the flow through C, be stopped, the water remaining around G, will be cooled and ultimately frozen. If then, a brine whose freezing temperature is low, be substituted for the water in C, it may be piped away for cooling storage space or may freeze cans of water immersed within it for ice making purposes.

FIGS. 5,531 and 5,532.—*Text continued.*

babbitt metal into hole B, from which it will run around groove C, and into holes D. Continue pouring until the babbitt has completely filled the groove and holes, and overflows at B. Remove the clay after the babbitt metal has set, and chip or file off any surplus, so that it is flush with the piston

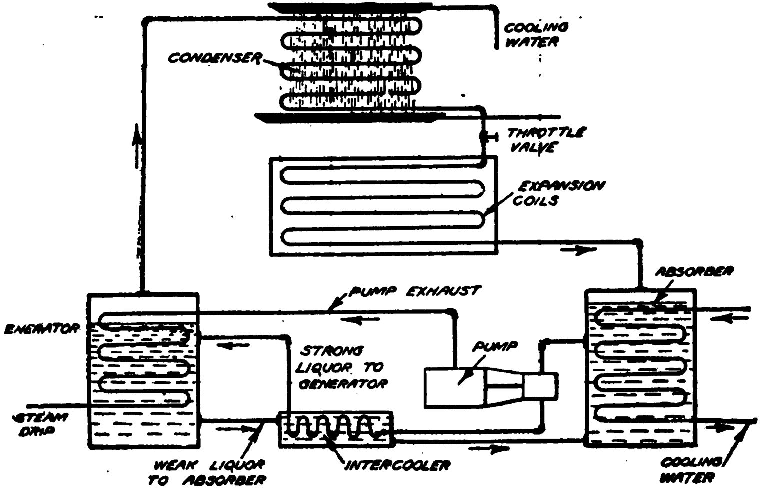


FIG. 5,534.—Elementary ***ammonia absorption system; direct expansion cooling***. The essential parts are: 1, generator; 2, condenser; 3, expansion coils; 4, absorber; 5, pump; 6, exchanger. As compared with the compression system the absorber takes the place of the compressor. ***Cycle of operations:*** 1, the strong liquor vaporizes in generator; 2, ammonia gas produced in generator passes to condenser and condenses; 3, liquid ammonia from condenser passes through expansion valve and vaporizes in the expansion coils which produces the cold or refrigerating effect; 4, ammonia gas from expansion coils is absorbed by the weak liquor in the absorber, producing strong liquor; 5, the strong liquor is pumped from the absorber to generator via the exchanger, where the hot weak liquor passing from generator to absorber gives up some of its heat to the strong liquor, thus completing the cycle.

NOTE.—If a solution of NH_3 and water (ammonia liquor) be placed in a boiler, termed a "generator," and sufficient heat supplied by a steam coil be applied, both superheated NH_3 gas and steam will be driven off or generated. The total pressure existing in the generator is made up of the partial vapor pressures of NH_3 and H_2O. The vapors on leaving the generator are first passed through a cooler (termed a rectifier or dehydrator) which is connected with the cooling water supply. A temperature is maintained in the rectifier which is sufficiently low to condense out practically all of the water vapor, approximately 90 per cent., but not the ammonia. The condensed water reabsorbs some of the NH_3 gas and is dripped back into the generator as rich liquor. This leaves practically dry NH_3 gas to be passed to an NH_3 condenser to be liquefied. The liquid NH_3 is then expanded in evaporating coils and refrigeration produced as in the compression system. The expanded NH_3 gas leaving the evaporating coils passes to the "absorber" where it is reabsorbed by the weak liquor drawn from the bottom of the generator. The rich liquor produced by the absorption is then pumped back to the analyzer and generator to repeat the cycle. The analyzer, located on top of the generator, consists of a series of trays over which the rich liquor flows on its way to the generator. The function of the analyzer is to reduce the superheat in the discharge gases, thus relieving the rectifier or dehydrator, and condenser of a part of the heat to be removed in the condensation of the superheated vapors. The analyzer is frequently omitted in order to lower the first cost of apparatus at the expense of economy in operation. The pressure existing in the generator and rectifier is determined by the temperature maintained in the condenser, which in turn is dependent upon the amount and temperature of the condensing water supply available.—*Harding and Willard.*

Ammonia Absorption System.—In this system the compressor is replaced by a vessel called the absorber, where the expanded vapor takes advantage of the property of water or a weak ammoniacal liquor (called the "weak liquor") to dissolve ammonia gas. (At 59° Fahr. water absorbs 727 times its volume of ammonia gas.)

The principle of the absorption system may be stated as *the alternate repulsion and absorption of ammonia gas by the alternate heating and cooling of ammonia water.*

In the elementary absorption plant the essential parts are:

1. Generator
2. Condenser
3. Expansion coils
4. Absorber
5. Pump
6. Exchanger or intercooler

these being shown in the diagram, fig. 5,534.

The cooling agent (ammonia water mixed in proportions of about one and two respectively), is placed in the *generator*, where it is heated by steam coils containing low pressure steam, usually the exhaust from the circulating pump, and due to this heat, ammonia gas under pressure is liberated from the water and passes on to the condenser where it is cooled and liquefied.

The liquid ammonia then passes into the expansion coils, where it vaporizes and absorbs heat from the surrounding substances thus providing the refrigerating effect, and the warm gas from these flows into an absorber, a tank containing the weak ammonia water (called the "weak liquor"), that is, that which has previously given up its gas in the generator. In the absorber are coils containing cold water, and the ammonia vapor coming from the expansion coils is absorbed by this weak liquor, and the heat given up by the gas in the absorption process is carried off in the cooling water. The strong liquor or strong aqua ammonia resulting from the absorption of the ammonia gas is pumped into the generator where it is again driven out of solution by the heating coils, thus completing the cycle.

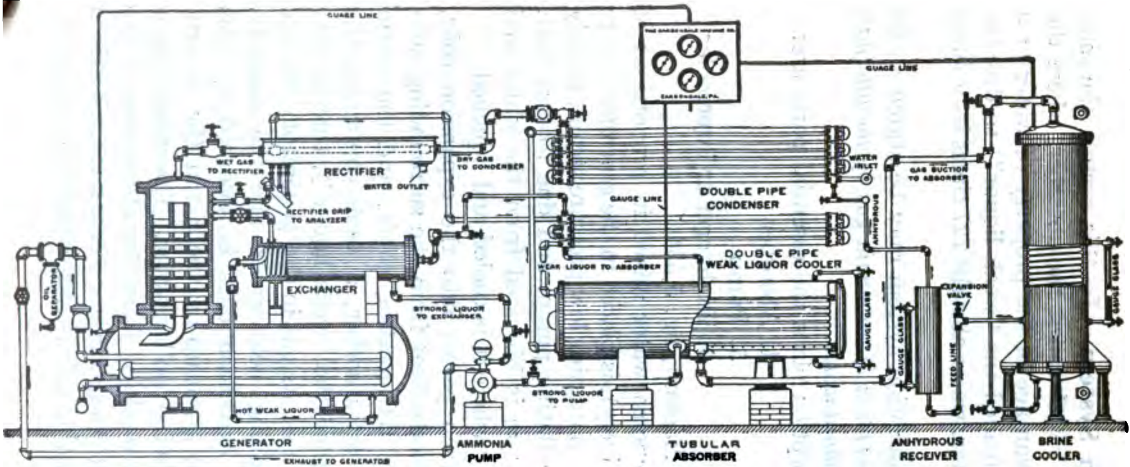


Fig. 5,535. Elevation of an ***absorption plant.*** The ammonia is evaporated out of the rich liquor in the generator and analyzer, and passes off into the rectifier; from the rectifier the gas passes to the condenser. The anhydrous ammonia passes from the condenser to the liquid receiver which is simply a reservoir. The receiver is connected to the expansion valve by a pipe of comparatively small size. The expansion valve is regulated so as to allow enough ammonia to enter the cooler to keep the latter at the required temperature. From the cooler the ammonia vapor is led to the absorber into which the poor liquor is sprayed, coming from the exchanger and passing through the weak liquor cooler. The rich liquor is taken from the absorber by the pump and discharged through the exchanger into the analyzer from whence it flows into the generator. The poor liquor is forced by pressure from the generator through the exchanger. In the exchanger the outgoing poor liquor gives up part of its heat to the incoming strong liquor.

NOTE.—For the best results the following conditions are necessary (Voorhees): 1, The generator should have ample liquid evaporating surface to make dry gas; 2, The temperature of the gas to the rectifier should be as low as possible; 3, The drip liquor returned to the generator from the rectifier should be as hot as possible; 4, The gas from the rectifier to the condenser should not be over 10° to 50° hotter than the condensing temperature of the gas; 5, The exchanger should exchange upward of 90% of the heat of the hot weak liquor to the cold strong liquor. The weight of strong liquor pumped should be from 7 to 8 times that of the anhydrous ammonia circulated in the refrigerator. To produce one ton of refrigeration at 8.5 lbs. suction and 170 lbs. gauge condenser pressure, about 3.5 times as many heat units are actually used by an absorption machine as by a compression machine (compound condensing engine driven) but, owing to the low efficiency of the steam engine, due to the heat wasted in the exhaust and in cylinder condensation, the actual weight of steam used per hour per ton of refrigeration is the same for both.

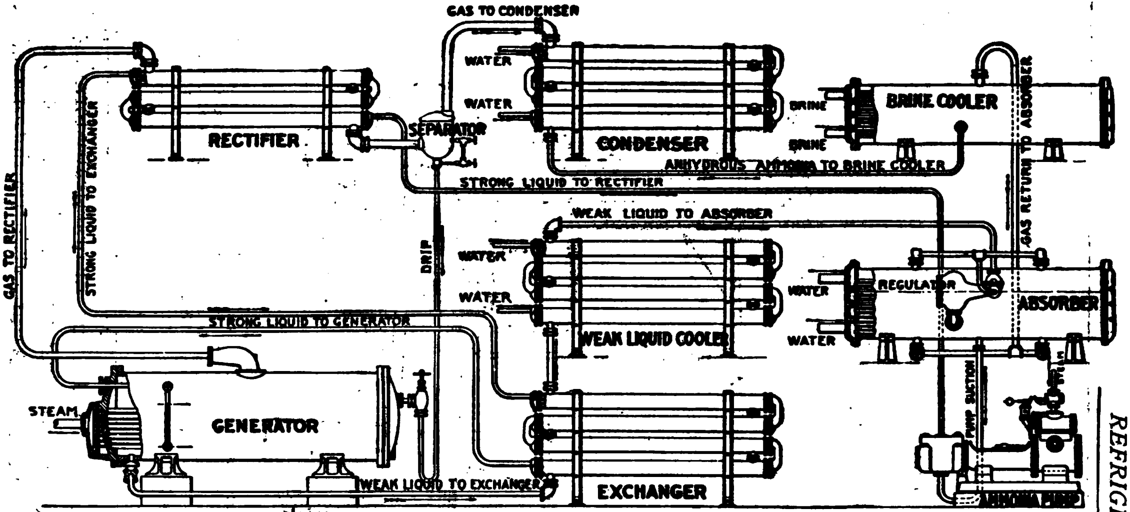


FIG. 5,536.—Vogt absorption refrigerating machine. Showing *pipe connections and directions in which the liquids and gases travel throughout the entire system. The machine here shown is of tubular construction.*

The cold strong liquor in going to the generator, passes through a coil in the exchanger and absorbs some of the heat from the hot, weak liquor which passes over the coil in the exchanger in passing to the absorber.

This exchange or transfer of heat in the exchanger relieves the generator and absorber of just so much work, thus increasing the efficiency of the apparatus in about the same way as a feed water heater does for a steam plant.

In the actual plant several additional parts are required for satisfactory operation, but the working principle as just outlined is the same. These additional parts are:

1. Analyzer.
2. Rectifier.
3. Cooler.

The operation of the complete plant is shown in fig. 5,535.

Ques. What is the analyzer?

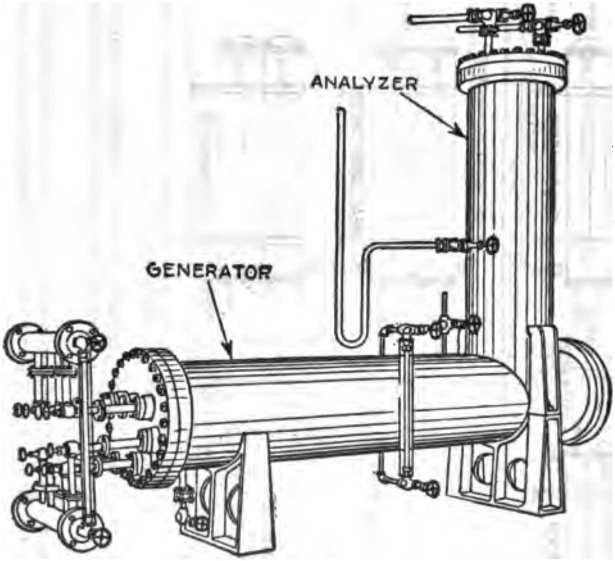


FIG. 5,537.—York generator and analyzer. The analyzer shell is welded to the generator body. The longitudinal seams are also welded which makes an absolutely seamless construction. A partial cross section, showing detailed description and end elevation of this generator and analyzer, is shown in fig. 5,538. It is especially constructed to be used with the York ammonia pump.

Ans. It consists of an upright cylinder placed upon the generator, if the latter be a horizontal one, or practically forming the upper part of it if it be a vertical one. It is sometimes made part of a horizontal generator. Arranged in the interior of the analyzer is a series of shelves and a corresponding number of basins below them.

Ques. Describe its operation.

Ans. The strong liquor is forced into the upper part of the analyzer by the ammonia pump, and as it falls on the boiling liquor below, it passes over these plates and basins and the vapor passing upward increases in strength, while the strong liquor passing downward is constantly rising in temperature. The channels of the analyzer must be large enough to allow this passage without foaming or interference.

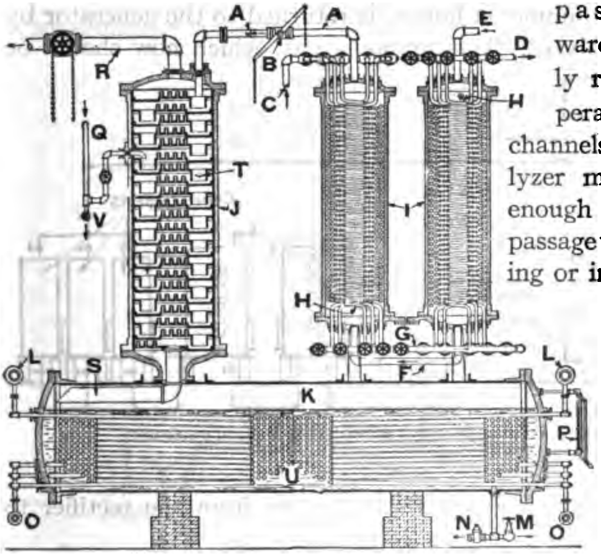


FIG. 5,538.—Polar generator, analyzer and heat exchanger for low pressure exhaust steam. The steam enters at L L, and after passing through and condensing in the coils U, goes out at O O, the coils are contained in the shell K, which forms the body of the generator and a receptacle for the liquor. The rich liquor from the ammonia pump enters at E, and after passing through the exchangers I, and the pipe F, is led to the analyzer J, by means of the pipe A. The pipe A, is provided with a stop cock which can be quickly operated by means of chains attached to a lever. In the analyzer the rich liquor flows over a number of pans T, where it comes in contact with the rising hot gas, and after circulating over all these pans it drains into the generator through the pipe S. The vapor from the analyzer passes to the rectifier by means of the pipe R; the rectifier drip Q, enters the analyzer, as shown, and is provided with a drain V, for blowing off. The weak liquor leaves the generator at N, and enters the exchanger coils H, at C; after going through the primary exchanger it passes by means of the manifold pipe G, through the secondary exchanger coils and header pipe D, to the weak liquor cooler, and finally into the absorber where it again unites with the anhydrous vapor. (See also on opposite page).

The object of the analyzer is simply to assist the generator in separating the ammonia gas from the water which absorbed it in the absorber.

Ques. Describe the rectifier.

Ans. It consists of a vessel having a water cooled coil. The hot ammonia gas, after leaving the analyzer, passes through this coil where any water vapor which may have escaped condensation in the analyzer is here condensed. This condensate, which is strong ammonia liquor, is returned to the generator by way of the analyzer. The ammonia gas, which now should be practically free from water vapor, passes from the rectifier to the condenser.

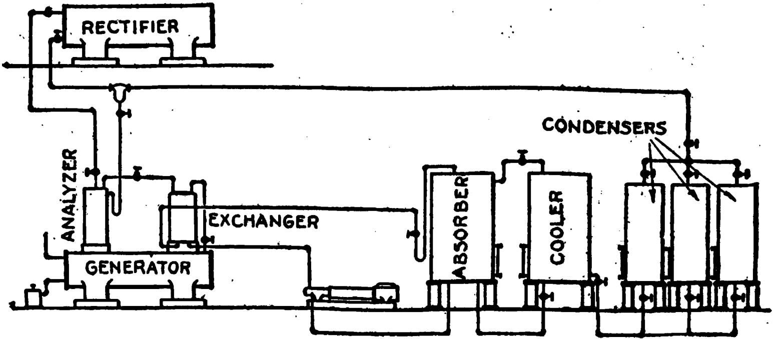


FIG. 5,539.—Diagram of polar absorption system with shell and coil condensers.

Ques. What is the objection to a very small percentage of water vapor in the gas?

Ans. It cuts down the capacity of the plant considerably.

Ques. Describe the cooler and its use.

Ans. The cooler consists of a vessel provided with a cooling coil. In operation it does for the weak liquor the reverse of what the heat exchanger does for the strong liquor, that is, it cools the weak liquor.

ABSORPTION SYSTEM PARTS

Generator.—This apparatus, also called the still or retort, is a large heavy shell or cylinder which should be capable of standing a pressure of 500 pounds per square inch.

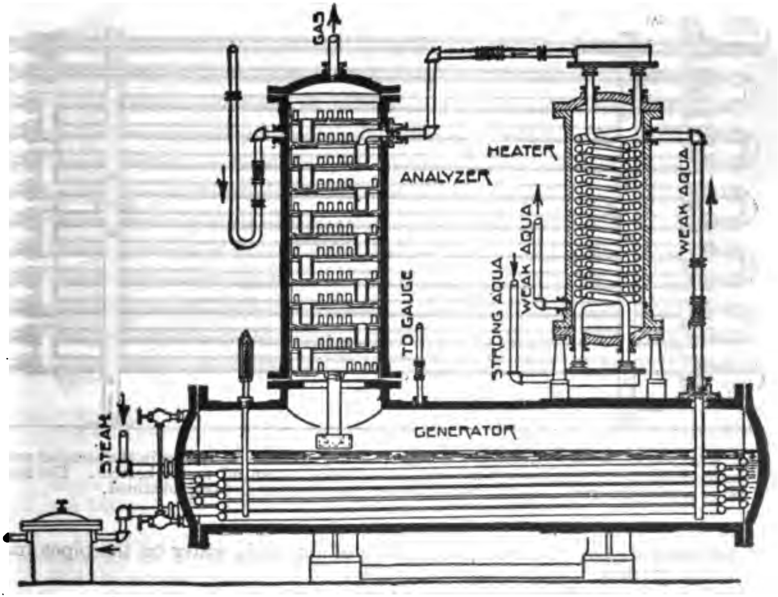


FIG. 5,540.—Polar generator for live steam.

It may be placed horizontally or vertically, its distinguishing feature in the interior being a steam coil which heats the strong ammonia liquor that is taken from the absorber by the ammonia pump and forced into the generator through the analyzer. Horizontal generators are better than vertical because of the larger liberating surface which is desirable because of the very rapid boiling of the liquid.

The coils occupy about half the height of a vertical generator, and a hood or inverted cone should be placed over them so that if the level of the liquor should fall so as to expose them, the rich liquor will not fall on them.

The generator liquor reaches the analyzer at from 150 to 170 degrees F. and is heated to about 200 degrees when it reaches the boiling liquor in the bottom of the generator.

The generator has an outlet in the lower part for taking the weak liquor back to the absorber.

The liquor level in the generator should be maintained above the upper coils, otherwise a chemical change in the ammonia might occur, forming a permanent gas; moreover, the falling of ammonia water on the pipes may cause pitting.

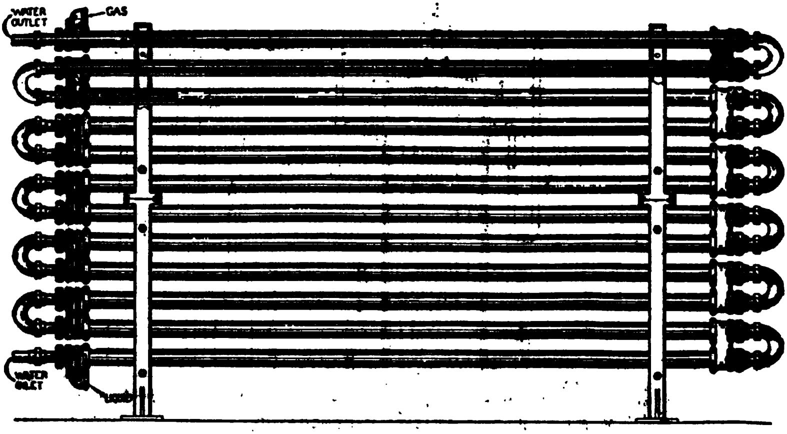


FIG. 5,541.—Double pipe ammonia condenser. The gas enters at the top in the annular space between the outer and inner pipes, the liquid being drawn off at the bottom. The inner pipes are for the water, and thus the counter current effect is easily obtained.

In case of trouble in the operation of an absorption plant steam should at once be shut off from the generator. Generators should be opened and examined internally from time to time to clean the tubes and make any necessary repairs.

A "boil over" causes the ammonia charge in the generator to be drawn out of the generator into other parts of the system; it may be caused by an insufficient charge in the system, by defective working of the pump, or some derangement in operating conditions.

To guard against a boil over, the generator glass should be closely watched to see that the coils are always covered with liquor.

Analyzer.—This consists of a vertical cylindrical vessel placed on top of the generator and forming a part of the latter. Inside the analyzer is a multiplicity of metal trays over which the cool, rich liquor from the exchanger passes, coming in contact with the hot ammonia vapors rising from the generator, especially as it trickles from tray to tray. The advantage of this counter current arrangement is that it has the effect of condensing and returning to the generator a large percentage of the entrained water vapor passing off with the ammonia, and also of liberating some ammonia gas through the heating of the rich liquor.

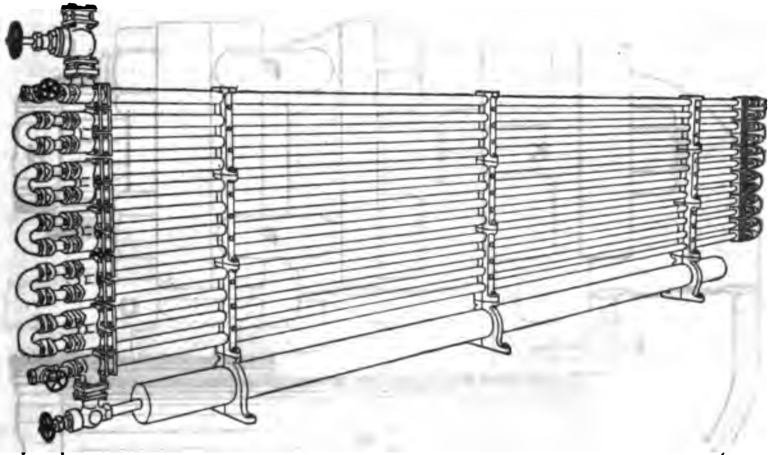


Fig. 5,542.—Double pipe ammonia condenser with receiver attached. The drum at the bottom of the coils forms the receiver space; this arrangement simplifies the piping considerably.

The analyzer should be kept clean, for if the trays become clogged, their capacity for handling the liquor is lowered, the analyzer will become flooded, and the ascending gas will carry liquor over to the rectifier.

Rectifier.—The object of the rectifier is to take the last trace of moisture from the hot ammonia gas before it reaches the condenser. Inside the rectifier is a small cooling coil and as the ammonia gas cools the small amount of water vapor that may be condensed drains back to the analyzer.

The efficiency of the machine depends very largely on the proper working of the rectifier. If it be not kept at the proper temperature there will be trouble. If it be allowed to run too hot the moisture held in suspension by the gas will not be removed, and will pass into the condenser and liquefy with the gas. If it be run too cold, both the moisture and the gas will be condensed and returned to the generator, leaving no gas to go to the condenser to supply the cooler. If it be allowed to become too cold it may cause a "boil over."

The proper working of the rectifier is indicated by its temperature as ascertained by the thermometer; the drain pipe should feel warm to the hand.

The water supply, which can be by passed, if necessary, should also have a thermometer so that the supply can be regulated.

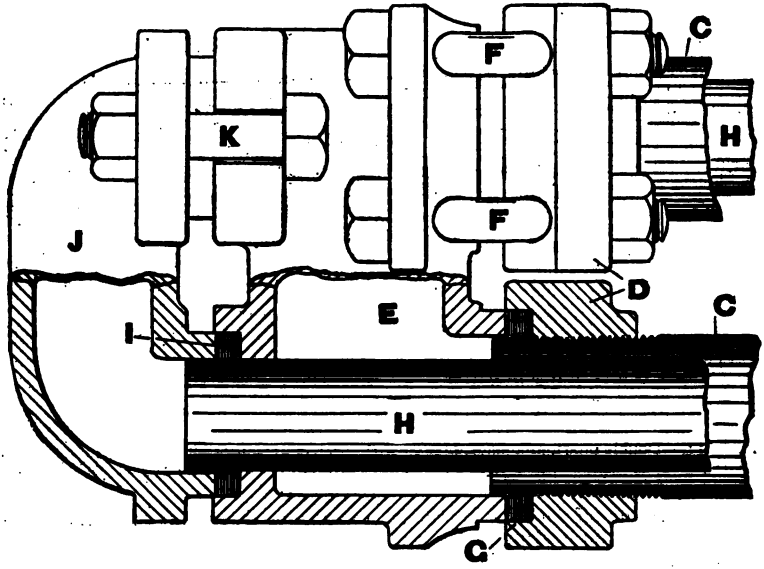


FIG. 5,543.—Detail of double pipe return bend. The ammonia pipes C, C, are screwed into the flanges D, and to these flanges the casting E, is held by the bolts F, F, compressing the soft packing G. The inner pipes H, H, are for the water circulation, the joints being made tight by means of the soft packing rings I, around each end of the pipe, which are compressed by the return bend J, and the bolts K.

If there be more moisture in the ammonia gas than the rectifier can separate, this moisture must go to the condenser and from there to the cooler, and moisture will not evaporate in the cooler, but takes up room and interferes with the evaporating ammonia gas, and must be purged before the machine will do good work.

If the engineer suspect the rectifier be not working properly he can test the ammonia for water by taking a 12 inch glass test tube, or, if this cannot be had, a 1 inch pipe about 12 inches long capped at one end. Bend a piece of wire about a foot long around one end of the tube or pipe so that it can be held away from the hand. Take a piece of pipe about the same size as the cock on the ammonia receiver and bend the threaded end so that the pipe will stand vertical when in position on the drum. Slip the test tube over the pipe until the end reaches almost to the bottom of the tube. Open the valve gently and draw a certain number of inches of liquid anhydrous ammonia into the tube, withdrawing it from the bent pipe as it fills. After noting carefully the amount of liquid in the tube, pour it in a shallow vessel and set the vessel in cold water or on a block of ice. Under these conditions, the ammonia will evaporate quickly and any residue remaining is the amount of moisture and impurities originally in the ammonia. Divide the amount of residue by the quantity of liquid drawn into the tube and multiply the quotient by 100, which gives the percentage. Before the liquor is drawn into the tube, a little gas should be allowed to escape in order to purge the test pipe.

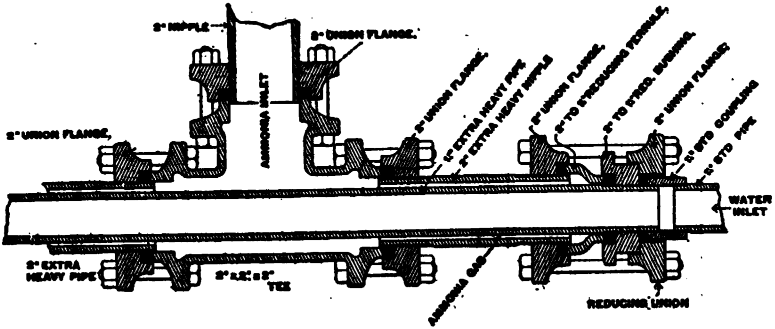
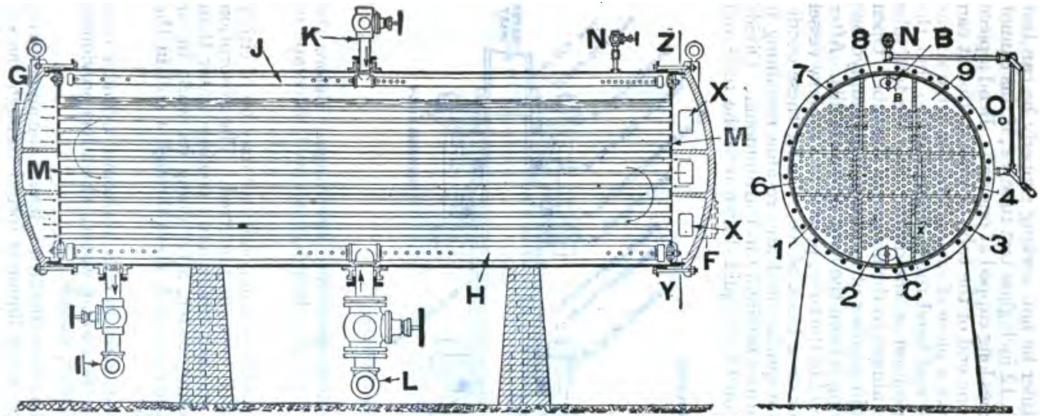


FIG. 5,544.—Water connection to double pipe condenser.

Condenser.—For absorption machines, the condenser may be of either the atmospheric double pipe or shell type, as preferred. The absorption system requires about two and one-half times more cooling water than the compressor system. The cooling water, after doing its work in or over the condenser, according to the type used, flows through a coil in the absorber, then through the rectifier.

Absorber.—One type of absorber consists of a horizontal cylinder containing coils of pipe through which the cooling water, which has previously done duty in the ammonia condenser, passes.

When the gas in the generator has been distilled it leaves the aqua weak, especially at the bottom, and this weak liquor is forced through the exchanger to the top of the absorber, where it is thrown over the incoming



FIGS. 5,545 and 5,546.—Polar multi-tubular absorber. Fig. 5,546, section through ZY of fig. 5,545. ***In operation,*** the weak liquor enters the top of the absorber through the pipe K, and is distributed by means of the sprinkling pipe J. The anhydrous vapor coming from the coolers enters at L, and is distributed by the perforated pipe H; both pipes are provided with caps at their extremities, which may be removed after opening the handholes B and C, and thus be cleaned out with a tube cleaner and a hose. The weak liquor is compelled to pass all the absorber tubes M, by being deflected from a direct downward course by the baffle plates, as shown. The flow is sufficiently slow to give the rising gas ample time to come in contact with the strengthening liquor and be fully absorbed. The cooling water enters at F, connected with the compartment 1, in the front head on this page; it then passes through the row of tubes ending in this compartment; then returns through another row of tubes to compartment 2 and through the first opening X, enters compartment 3, and so on until it finally leaves the absorber at G. The strong liquor leaves the absorber through the pipe I, and being taken up by the ammonia pump is finally returned through exchangers and analyzer to the generator. The liquor level in the absorber may be observed by the gauge O, and a pressure gauge should be connected to N.

gas and the water coils in a spray by means of a valve for that purpose at the top.

It is necessary to pass cooling water through the absorber because the lower the temperature of the weak liquor, the greater its power to absorb the ammonia vapor coming back from the refrigerating coils. The absorber should be placed as near the expansion coils as possible. The pipe conveying the gas is brought into the absorber about in the center, and should be so arranged that the vapor will not fall directly on the water coils.

There are numerous methods of spraying the weak liquor at the top of the absorber. One is simply a valve with three oblique holes. If one side of the absorber get warmer than the other, turn the valve slightly down, say one-eighth of a turn, and by a little manipulation the all over temperature of the absorber can be maintained even. Sometimes a little scale or dirt will get over a hole and partly close the valve.

The flow of the weak liquor is regulated by a valve near the exchanger, that at the generator being used only to shut off the weak liquor altogether. There should be only enough weak liquor thrown over to absorb the gas. More than this puts an extra load on the ammonia pump, exchanger and absorber.

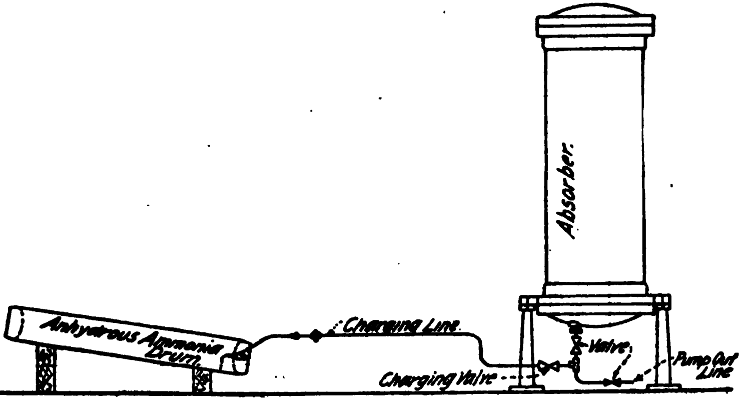


Fig. 5,547.—A safe method of charging an absorption plant, but the refrigerating effect of the drum of ammonia is lost.

The supply of weak liquor as it enters the absorber is usually controlled by an automatic regulator. This apparatus, when once set, requires scarcely any attention, thus enabling the engineer to pay more attention to other matters. On the other hand, if the weak liquor entering the absorber be regulated by hand, he cannot leave the engine room with safety for any length of time, because the amount of weak liquor entering the absorber varies with both the generator and absorber pressures.

The strong liquor passes out of the absorber near the bottom to the pump which forces it through the exchanger to the analyzer, where it falls by gravity into the generator.

The absorber must be cleaned frequently, because the cooling waters used in the operation of absorbers usually contain carbonates of lime, magnesia, and iron, which become insoluble at the temperature of the absorber because the free carbonic acid is driven off from the water which holds them in solution.

The coils should be kept clean by blowing them out occasionally with steam or compressed air, and where hard water is used this should be done at least once a week. In fact, cleanliness and regularity of operation are the main things to look after in an absorption plant.

The absorber may sometimes show too high pressure because of too much liquid in the system or too little cooling water; it may also be due to permanent gases in the system.

A leak in one of the cooling coils of the absorber will at once be noticed in making a test of the cooling water after it has passed through the coils.

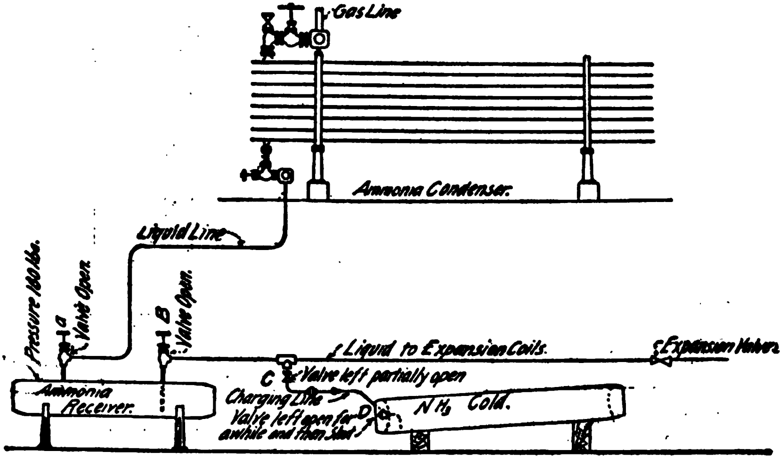


FIG. 5.548.—A rather dangerous method of charging a plant, but the refrigerating effect of the ammonia is preserved.

Should a leak be indicated, steps should be taken to locate the defective coil at once, as in the case of a leaky coil in the generator.

The main point of operation with the absorber is regulating the liquor level and it is now a recognized fact that the larger part of the attention required for doing this properly should be given by an automatic regulating valve for controlling the flow of the liquor. Air and burnt gases should at all times be kept purged off the absorber.

It can be noticed at any time whether the absorber is taking hold well and by the frost on the gas pipe. If the frost continue white and keep accumulating, the absorber is working uniformly; if the pipe begin to thaw, either the absorber has "let go," or the cooler has become foul.

At the bottom of the absorber is a purge valve. The pipe from this should have a swivel joint so it may be swung into or out of a bucket. If there be air in the system, it will usually be found at the bottom of the absorber and should be drawn out through this valve. The valve should be opened occasionally to test the system for air.

A clean machine ought to run from one to two months without trouble of this kind. To test it, get a bucket of cold water, and set it under the outlet to the pipe and open the valve from one-eighth to one-fourth turn. If air be present, bubbles will rise to the top of the water, nearly noiselessly. Should there be few bubbles, accompanied by a crackling sound, like water being heated with steam, it indicates the presence of gas, showing that that part of the machine is all right.

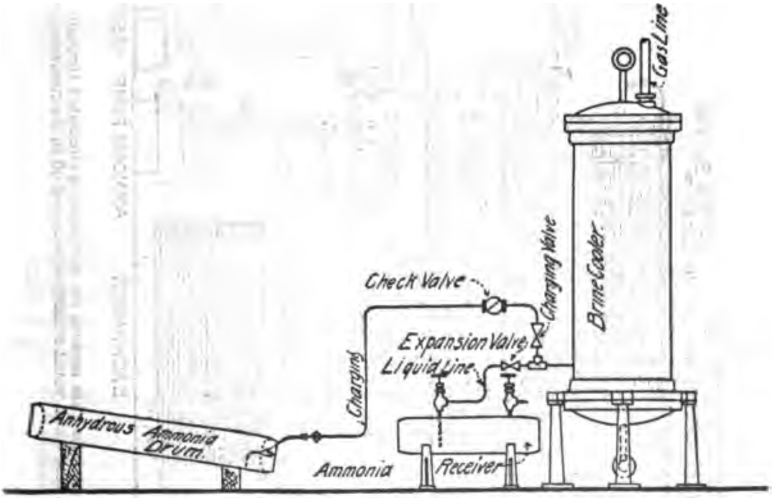


FIG. 5,549.—Correct method of charging a plant equipped with brine circulation.

When air bubbles are rising, if a match be held over the pail and a pale yellow flame result, it shows that there is some foul gas mixed with the air.

Half way up the absorber there is another purge pipe for drawing off foul gas. If this valve be slightly opened and the gas issuing therefrom be lighted and continue to burn of itself, it shows foul gas.

There is difference of opinion as to the amount of liquor to carry in the absorber to take up the gas coming from the freezing tank coils. The proper amount can be ascertained by testing the rich liquor passing through the ammonia pump at different heights in the absorber, that is, if the rich liquor indicate 26 degrees at a certain height and 25 degrees at an

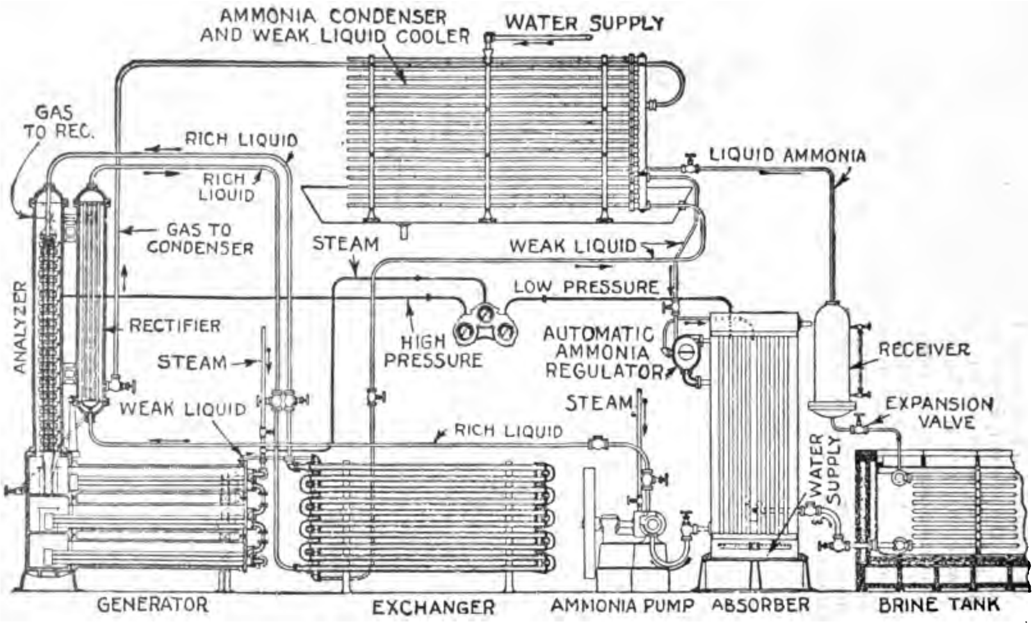


FIG. 5,550.—**Large absorption plant.** ***In this system*** **the rich liquor is circulated through the rectifier before passing through the exchanger, thus some of the heat which would otherwise be carried off in the condensing water is saved.**

additional height it is a sure indication that the limit has been reached, because the weak liquor absorbs all the gas coming from the coils and yet fails to bring the rich liquor up to the standard.

This is detrimental, for it requires more heat to extract the same percentage of gas from the 25 degree aqua ammonia than from 26 degree.

When the absorber is cold the poor liquor within it will have a large absorbing power and take gas from the cooler all right, even if it be gas of medium high percentage; if it grow warmer, it will have less absorbing power and do less work.

If the temperature cannot be improved because of insufficient water or because of the high cost of the water, the liquor coming over must be made weaker, by turning more heat on the generator and distilling more of the gas over into the condenser, which will carry a large amount in storage.

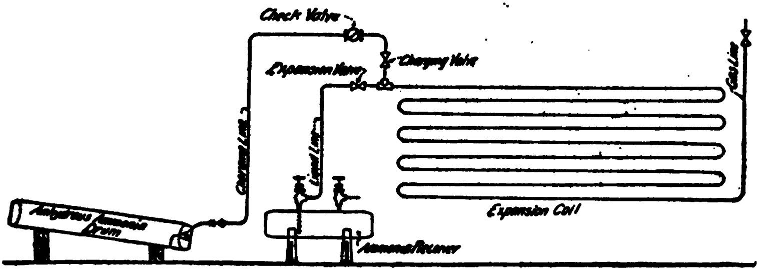


FIG. 5,551.—Correct method of charging a direct expansion plant.

It will also be found that the cooler will need a little more gas under this condition. This weakens the whole charge in the generator, requiring higher heat in the coils and a higher pressure to distill the necessary gas from the weakened charge, and this is the reason a higher pressure has to be carried with a warm absorber.

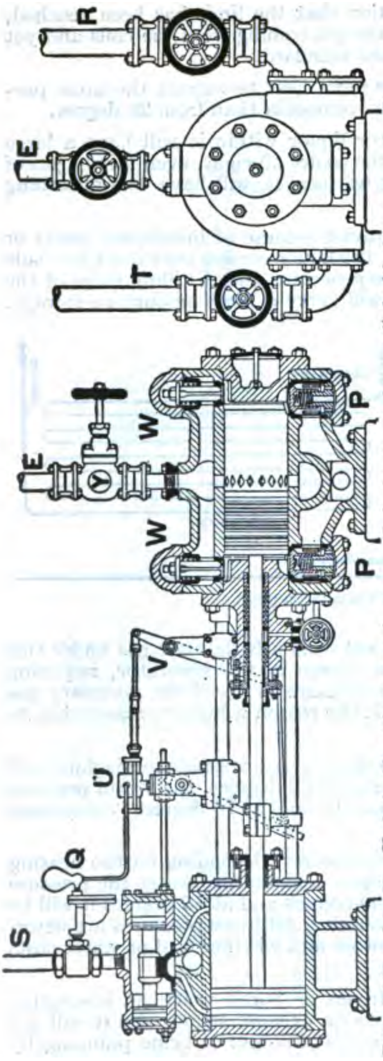
With cooling water at or below 60 degrees, a low pressure machine will run at atmospheric pressure; with water at 70 degrees, the steam pressure may have to be raised two or three pounds; and at 75 degrees it may have to be raised to 10 pounds.

Some machines will require higher pressures, depending on the heating surface in the generator. With 60 degree temperature water the pressure in the generator may be from 90 to 100 pounds and at 75 degrees it will be necessary to carry it to 150 or 160 pounds. All these pressures are determined by the temperature of the absorber and whether coal or water costs the more.

If water can be obtained from driven or bored wells, an absorption machine can be run the year through with exhaust steam, and it will not act as a brake on the engine. Where there is lots of brine pumping by steam pumps it is possible to run a machine with the exhaust from the pumps.

Conditions as regards water should be carefully investigated before deciding on the site for a plant.

Dead liquor may be expelled from the cooler into the absorber by shutting off the return gas line from the cooler to the absorber and opening a line from the bottom of the cooler to the absorber. This shuts down the machine during the process of pumping out, and the temperature of the brine goes up, often 10 degrees or more, and may require two to four hours. The liquor is evaporated and taken up in the absorber by the weak liquor. Shutting down a machine for this purpose may really cause a high temperature brine for several hours. To overcome this, the pipe at the bottom of the cooler may be connected with the liquor line from the absorber to the pump by a one-inch pipe and a gate valve. It is understood that it would not do to attempt to open this valve wide or to attempt to pump it out unless there was a good



FIGS. 5,552 and 5,553.—York double acting ammonia pump. S, is the steam pipe supplied with the governor Q. The governor consists of a diaphragm which operates the governor valve. The small hydraulic cylinder U, contains a piston operated by the piston rod through the lever V. When the speed of the pump increases, the pressure upon the diaphragm is increased by the hydraulic piston, and thus the governor valve is partly closed. The strong liquor enters the pump through the pipe R, and the suction valves W-W, P-P, are the discharge valves, and T, the discharge pipe which leads to the heat exchanger. The pump cylinder is provided with a number of small ports around its center, which by means of the annular channel connect with the equalizing pipe E. At the end of the suction stroke the pump piston uncovers these ports, and any gas that may have formed during suction will pass through E, into the absorber to which this pipe is connected. The pump in all cases must be set below the absorber.

Giving two to two and one-half turns on this gate valve would clean out the cooler as quickly as the old way and the operation of the machine would not be interrupted, but the temperature of the brine would go down during the process. The machines should be run in the usual manner during this operation and nothing changed, except to partially open the valve at the bottom of the cooler, as described. It saves a lot of labor and keeps the brine temperature down.

It would be a good plan to provide this pipe with a check valve to prevent liquor from the absorber backing into the cooler.

Ammonia Pump.—This is a specially constructed pump so designed as to prevent any leakage of ammonia through the stuffing box.

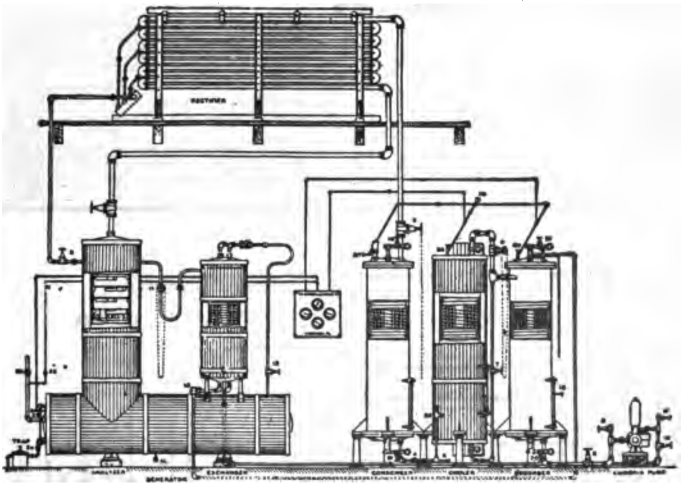


FIG. 5,554.—Carbondale shell type machine.

NOTE.—***Condensers*** for refrigerating machines are of two kind: 1, submerged; 2, open air evaporative. The submerged condenser requires a large volume of cooling water for maximum efficiency. According to Siebel the amount of condensing surface, the water entering at 70° and leaving at 80°, is forty sq. ft. for each ton of refrigerating capacity, or 64 lineal feet of two inch pipe. Frequently only twenty sq. ft. or ninety ft., of 1¼ inch pipe, is used, but this necessitates higher condenser pressures. If F=sq. ft. of cooling surface, h=heat of evaporation of 1 lb. of ammonia, at the condenser temperature, K=lbs. of ammonia circulated per minute, m=*B.t.u.* transferred per minute per sq. ft. of condenser surface, t=temperature of the ammonia in the coils and $t_{,,}$ the temperature of the water outside, $F=hK \div m(t-t_{,})$. For $t=80$ and $t_{,,}=70$, m may be taken at .5. Practically the amount of water required will vary from 3 to 7 gallons per minute per ton of refrigeration. When cooling water is scarce, cooling towers are commonly used. E. T. Shinkle gives the average surface of several submerged condensers as equal to 167 lineal feet of 1 inch pipe per ton of refrigeration. Open air or evaporation surface condensers are usually made of a stack of parallel tubes with return bends, and means of distributing the water so that it will flow uniformly over the pipe surface. Shinkle gives as the average surface of open air coolers 142 ft. of 1 inch pipe, or 99 ft. of 1¼ inch pipe per ton of refrigerating capacity.

It is well to have a small connection from the poor liquor pipe to the suction pipe somewhere near the absorber, so that in case the pump get gas bound it can be remedied by simply opening the valve for a few seconds to charge the pump, thus saving the possible necessity of stopping the pump, removing the valve caps and charging the pump in that way.

Exchanger.—This apparatus may be of the shell and coil or double pipe type. It transfers the heat from the weak liquor of the generator to the rich liquor coming from the absorber. The temperature of the weak liquor may be 280° and the strong liquor 80° before passing through the exchanger.

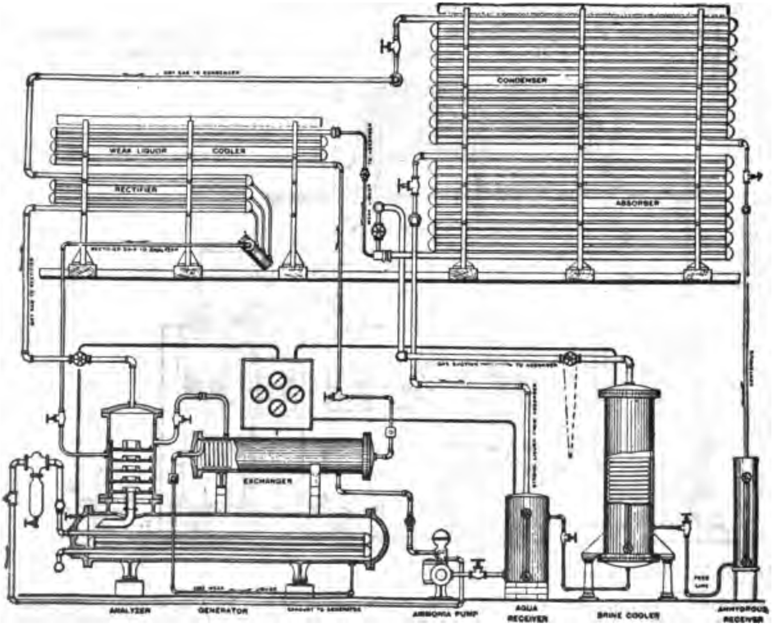


FIG. 5,555.—Carbondale atmospheric type machine.

A leak in the exchanger coils is one of the defects that the engineer locates while making his regular round of inspection and test. Ordinarily the rich liquor should show 28 degrees, while the poor liquor is 16 degrees. This shows excellent working and in some cases the plant may not show these results.

When the engineer finds that the strength of the rich liquor is 24 degrees,

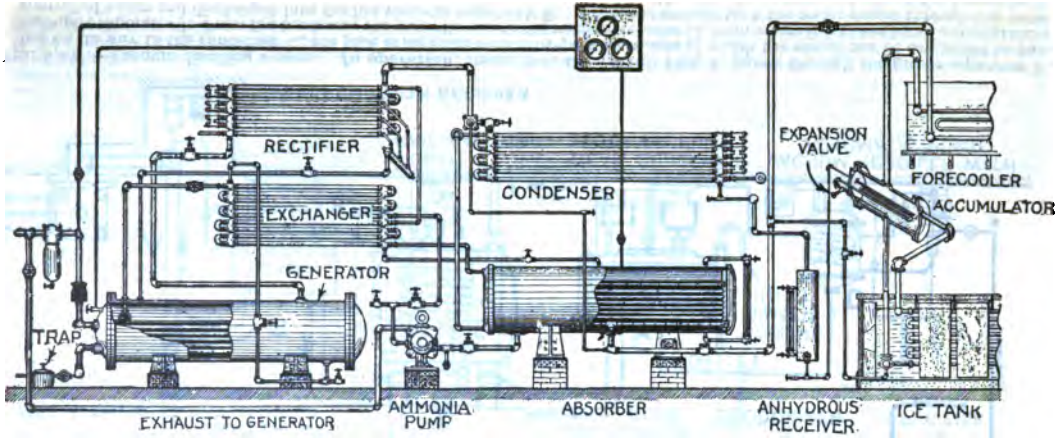


FIG. 5,556.—Carbondale flooded direct expansion system showing a tubular type absorption machine in connection with an ice making system. In this case, the liquid anhydrous ammonia from the anhydrous receiver passes through a coil in the accumulator, and is fed as illustrated through the expansion valve into the lower header of the direct expansion coils in the ice making tank. The anhydrous ammonia in the expansion coils evaporates, absorbing heat from the brine, and the gas, together with a certain amount of liquid ammonia in the form of spray or surge, leaves the upper header of the expansion coils and is delivered into the body of the accumulator. The anhydrous feed passing down the drain pipe from the bottom of the accumulator causes a circulation on the principle of an injector, which carries this entrained liquid along with the fresh feed, into the coils again. The gas which separates from the liquid ammonia in the accumulator, passes out of the top of the latter and through the coils in the fore-cooling tank where it is warmed, and any liquid in it evaporated; the distilled water in the fore-cooling tank, being cooled in the process. The gas passes on to the absorber as where a brine cooler is used. The coil within the accumulator, which the anhydrous feed traverses before it passes through the expansion valve, is for the purpose of pre-cooling the anhydrous ammonia and thus increasing the efficiency of the ice tank.

while the strength of the poor liquor has fallen in like proportion, he knows at once that the machine is doing the proper amount of work, but at the cost of extra fuel, as required to distill the rich liquor of lower density. Then again, when the test of the rich liquor shows a density of, say, 24 degrees, while the density of the poor liquor rises, the indications are of an exchange of ammonia, which means a leak in the exchanger coils. If the

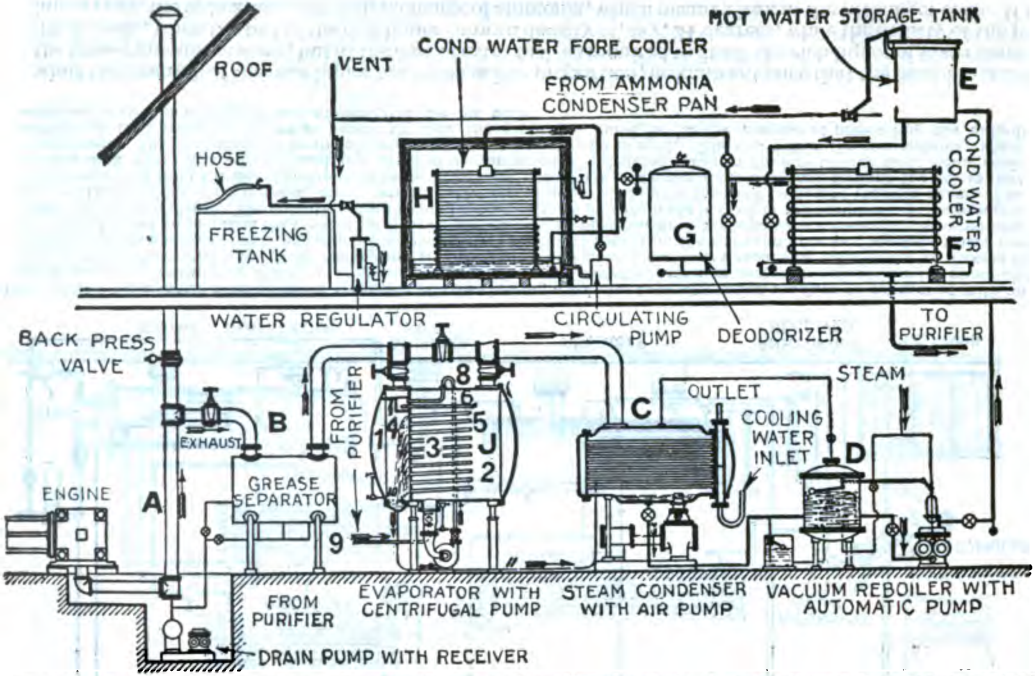


FIG. 5,557.—Vacuum distilling system. ***In operation,*** steam from the exhaust pipe A, passes through the grease separator B, but on its way to the condenser C, the pipe is supplied with a by-pass by means of which the steam can be compelled to pass through evaporator J. From the condesner the water flows into the vacuum reboiler D, from where it is taken by an automatically controlled pump and discharged into the hot water storage tank E. From the storage tank the water passes through the water cooler F, into the deodorizer G, and hence into the condensed water forecooler H. The flow of the water from the forecooler to

Fig. 5,557.—*Text continued.* the freezing tank is regulated by the regulator I. This regulator is controlled by the water level in the storage tank. A butterfly valve in the pipe to the freezing tank is held open by water pressure upon a piston in the cylinder I, but when the water level in the storage tank drops, a valve in the pipe supplying the hydraulic cylinder is closed by the dropping of a float, and as the water in the cylinder I, drains away, the filling pipe valve is closed by the descending piston. The pipe leading through the deodorizer is supplied with a by-pass to be used while cleaning out the deodorizer. The evaporator J, consists of a shell 2, supplied with a removable head 1. The exhaust steam enters the chamber 4, and is passed over a number of pans 3, into the chamber 5. A centrifugal pump circulates water over these pans, the water is discharged through pipe 8, into the header 7, and from there passes through a number of sprinkling pipes 6, over the pans. The water running off the pans is collected at 10, and again circulated by the pump. The exhaust steam passing through the evaporator takes up a large amount of vapor of the water, being heated in a vacuum, and carries this vapor over into the condenser.

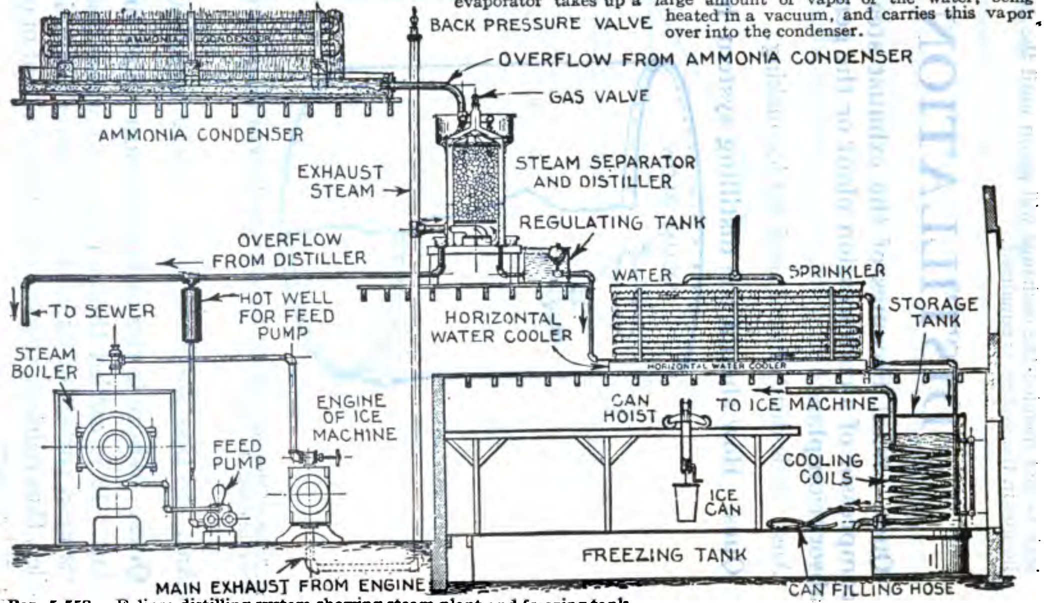


Fig. 5,558.—Eclipse distilling system showing steam plant and freezing tank.

leak be not mended the exchange will go on until the density of the two liquors in the system is equalized.

DISTILLATION

Ques. What becomes of the exhaust steam from the compressor of a compression plant or the generator of an absorption plant?

Ans. It is distilled and used for ice making.

Ques. How should the distilling system be arranged?

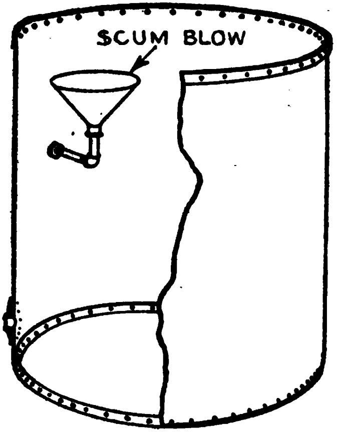


FIG. 5,559.—Skimming tank with funnel surface blower for removing oil or other light scum from the distilled water.

Ans. So that the entire system can be purged by steam.

Ques. Where is the exhaust steam taken first?

Ans. It is carried through the feed water heater where it gives up a portion of its heat to the water before it reaches the boiler, thus reducing to some extent the amount of coal necessary to make steam.

Ques. What is the next step?

Ans. The steam is now in a saturated condition, and it passes through an oil separator where it strikes against baffle plates, the impact having a tendency to separate the oil from the steam, it dropping to the bottom of the separator where it may be drawn off.

Ques. Describe in detail a diagram of a water distilling system.

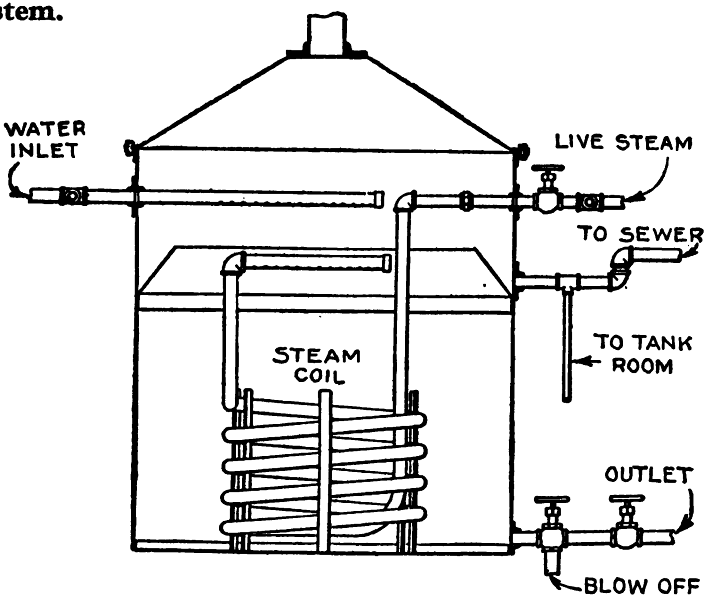


Fig. 5,560.—Reboiler for reboiling condensed water for ice making purposes, the process frees the water from air and foreign gases, oil or grease, etc. *In operation*, the heat from the coil causes the water to boil, thus forcing the grease or other impurities toward the surface, where an overflow pipe carries them into a trap, while the air and gases are taken off in a special flue. Reboilers of this shape are made of heavy galvanized iron and properly reinforced at top and bottom. A closed coil should be used in preference to a perforated coil. A perforated coil often gives to the water in the tank the appearance of boiling when the temperature is still below 212 degrees. Keep the reboiling tank up to 212 degrees, and run the waste steam from the reboiling coil into the steam condenser.

Ans. The exhaust steam, as shown in fig. 5,561, enters the surface condenser, A, and when condensed, the water flows from the condenser to the pump, B, which is placed below the condenser, thus the water can be pumped fairly hot into the reboiler, C, which is set on the roof of the building.

The reboiler is made of galvanized iron with a cover on it; two open ventilators are on top of the reboiler to allow the foul gases to escape. A live steam coil is placed near the bottom and the water as it enters comes in contact with it, which causes the water to boil and carry the impurities toward the surface; the air and gases are carried out through the ventilator. Attached to the reboiler is a compartment, E, for skimming the oil that rises to the surface of the water. The reboiler is skimmed automatically by an old time device, every twenty minutes or half hour, according to the amount of water distilled. The device used to regulate the skimming of the reboiler works as follows: the plunger and cylinder, F, which operate the lever valve, G, are placed far enough below the reboiler to get a head of water sufficient to raise the plunger in the cylinder. As

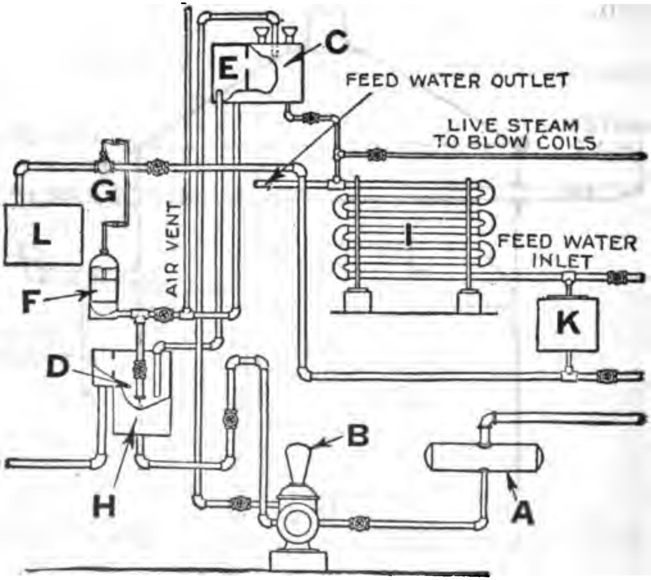


FIG. 5,561.—Water distilling system. Exhaust steam enters the surface condenser, A, and when condensed the water flows from the condenser to the pump, B, which is placed below the condenser, thus the water can be pumped fairly hot into the reboiler, C, which is set on the roof of the building.

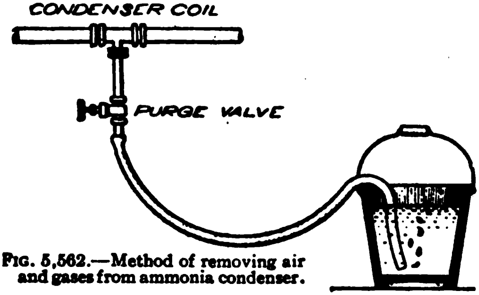
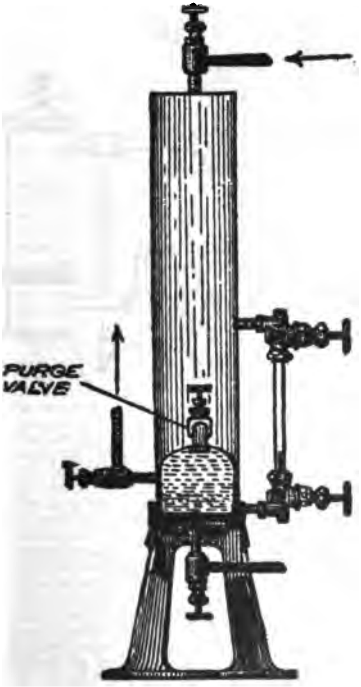


FIG. 5,562.—Method of removing air and gases from ammonia condenser.

the plunger rises, due to the pressure under it, the lever valve opens and allows the distilled water to flow out of the re-boiler. The length of time that the lever valve is open can be regulated by placing a cap D, on the outlet pipe to the tank H, which is used to catch the water and oil that is skimmed from the re-boiler.



Management of Refrigerating Machines.—Before starting refrigerating machinery, whether newly installed or after any considerable period of disuse, all piping and joints should be tested for leaks. This may be done, no matter what the system be, using the compression pump to compress air into the piping up to whatever pressure may be considered suitable.

The seriousness of the leakage may then be estimated by the rapidity with which the pressure is lost after allowing the pump to stop. The larger leaks may be determined by the noise made by the escaping air. For the smaller ones the joints are sometimes covered with soap suds so that the escaping air may show itself by blowing a cluster of bubbles. After the points which may show leaks have received proper

FIG. 5,563.—Oil separator as usually connected to the discharge of a compressor. It collects the oil which may accumulate in the pipe and also will act as a pressure tank. The oil may be drawn off periodically through the bottom cock, and any foul gas may be blown off by means of the purge valve.

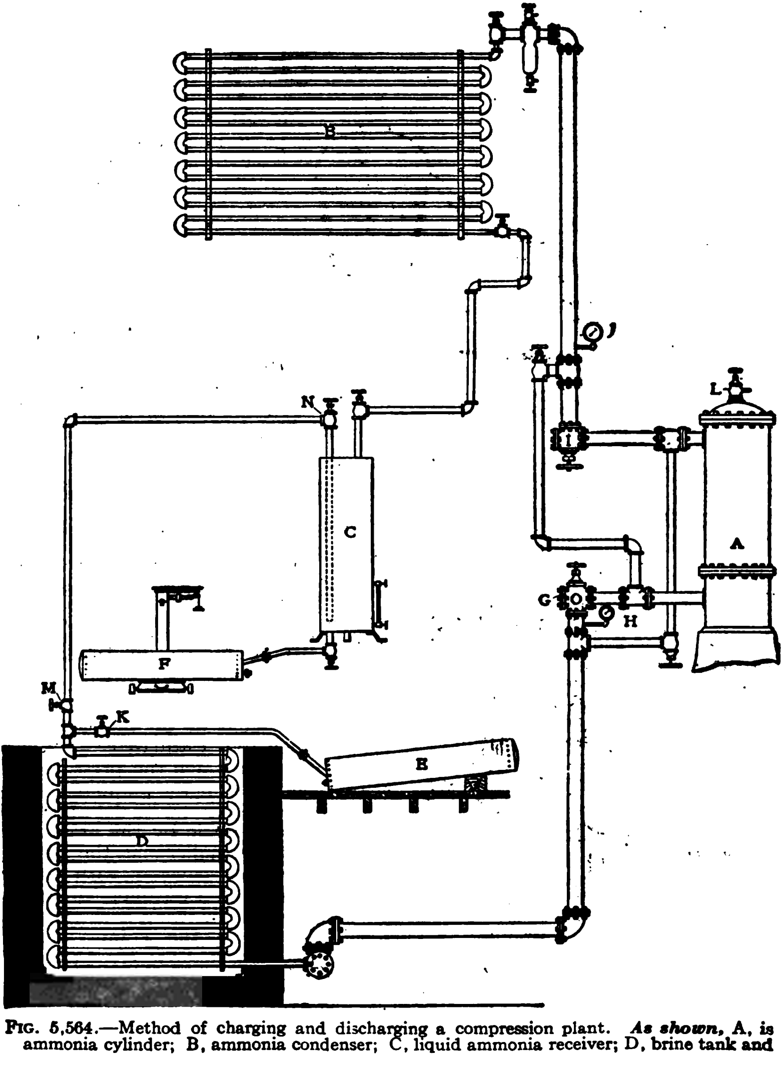
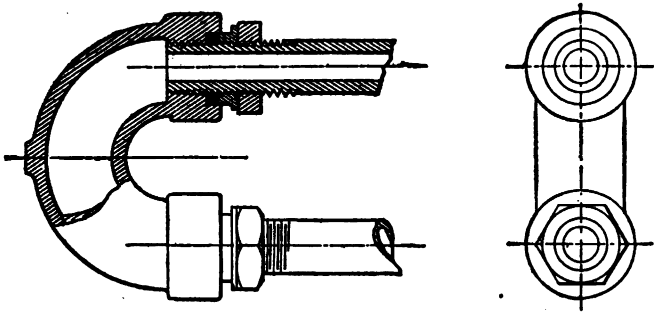


FIG. 5,564.—Method of charging and discharging a compression plant. *As shown,* A, is ammonia cylinder; B, ammonia condenser; C, liquid ammonia receiver; D, brine tank and

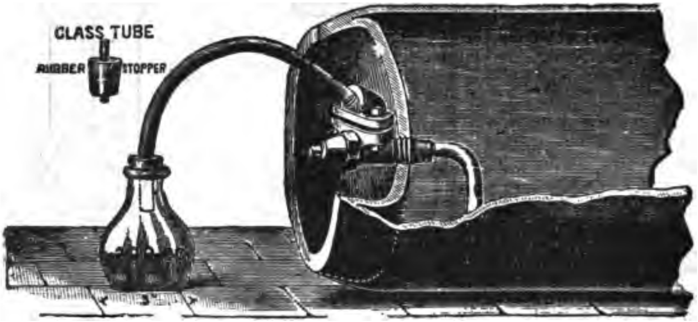


FIGS. 5,565 and 5,566.—Solid return screw joint bend with recessed ends, showing method of using latter as stuffing boxes to insure tight joints.

FIG. 5,564.—*Text continued.*

expansion piping. A drum of liquid ammonia connected to the system to charge the plant with ammonia is represented at E. At F, is a drum connected to the system to receive the ammonia when it is desired to empty the system. Valves to drums E and F, and purge valves on the trap and compressor are closed. Starting with valve I, all the valves on the main line, to and from the condensers, will be open; those on the receiver and brine tank will also be opened, so that there will be a clear passage from the discharge valve I, right around to the suction valve O. The by pass valves will be shut. Then shut the suction valve O, and remove the side bonnet G. This allows air to be drawn into the cylinder when the piston is moving. Then start the machine and run it until the low pressure gauge H, shows the pressure at which it is desired to make the low side tight. This is usually about 150 pounds to the square inch. This pressure is also high enough to find most of the leaks on the high side. After everything has been pronounced right the compressed air is allowed to escape through the purge valves on the trap and receiver, so that any loose scale and dirt will be kept away from the compressor. The system is now full of air at atmospheric pressure and this air must be removed before the ammonia is put in. To do this the purge valves that let the air out are closed. The expansion valves at M, are opened again. The compressor is now started and the air that the compressor exhausts from the system is discharged through the open purge valve L. To prepare the system for charging all the purge valves are closed, also the by pass valves and the expansion valves M. If it be impossible to get the charging connection into the line as shown it can be put anywhere on the liquid line between valves M and N. When charging the ammonia the valve N, can be closed. Either one of these valves must be closed to hold back the liquid. All the other stop valves on the line must be open.. A drum of ammonia is now connected to the system as shown at E. If there be a gauge glass on the liquid receiver it is quite easy to tell when there is enough ammonia in the system. It is only necessary to choke off the water on the ammonia condensers until the head pressure runs up to what it will be under full load, then the expansion valve M, is opened until the desired back pressure is obtained. The head or condensing pressure will be about 15 pounds more than the pressure due to the temperature of the condensing water as it leaves the ammonia condensers. The back pressure will be the pressure due to 10 degrees F. colder than the coldest brine or room. When the machine is running with these pressures there should be about six inches of liquid over the end of the outlet pipe shown by the dotted lines at C. ***To discharge,*** an empty drum is connected as at F. The empty drum is weighed and not more than 100 pounds of ammonia should be allowed to run into the drum, so as to leave room for expansion of the ammonia by heat. If the liquid receiver is in a warm room the empty drum should be covered with wet bags and ice laid on top of the bags. This will condense any vapor that may be formed in the piping or drum. Even with ice on the drum it is sometimes necessary to loosen up on the union between the receiver and drum to let out any dead vapor.

attention, the system should, for a considerable time, hold the pressure without sensible loss. In this connection, however, it must be remembered that the air as it leaves the compressor will be heated by the work of compression, and as it loses this excess heat in the coils there will be a



FIGS. 5,567 and 5,568.—Ammonia drum and detail of glass tube and rubber stopper showing method of testing ammonia for water. To draw a test sample of ammonia, a bottle is connected to the drum as shown, and a small amount of ammonia drawn off and allowed to evaporate in the bottle. Any water contained in the liquid will remain in the bottle and the percentage may thus be determined. The ammonia should be evaporated through a small glass tube inserted in a rubber stopper.

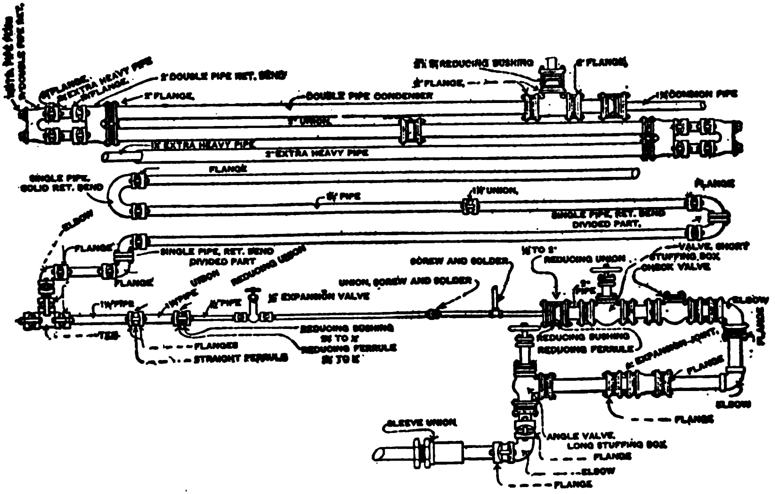


FIG. 5,569.—Different connections made with ammonia fittings.

corresponding loss of pressure. After equality of temperature with the outside air has been reached, however, the further loss of pressure should not be appreciable.

Ques. What examination should be made of air and of ammonia machines before operation?

Ans. With the air machine no further preliminaries are needed beyond the examination necessary to insure the proper mechanical condition of the compressor and steam cylinders. With the ammonia machine, however, it is necessary next to exhaust the air from the entire system by working the pumps and discharging through valves provided for this purpose.

When the gauges show the highest vacuum which can be maintained, the valves are closed and the system is ready for charging. The ammonia is usually provided in steel flasks containing a known weight of the liquid.

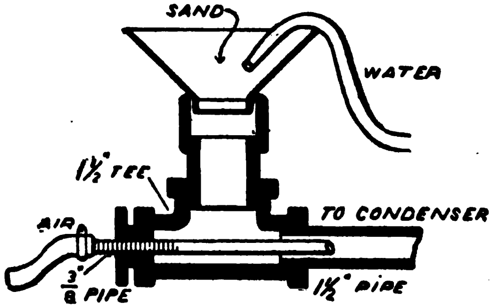


Fig. 5,570.—Ejector for cleaning out condenser pipes.

Sulphurous Acid System.—This system has been largely developed by Raoul Pictet. It has the advantage of requiring only comparatively low pressures, and sulphurous acid is a good lubricating medium. This fact simplifies mechanical details of the machine and it is in use to some extent on the continent of Europe for small plants where the service of a skilled engineer is not practicable.

The main objection to the use of this refrigerating agent is the great tendency of sulphurous acid to take up moisture and change to sulphuric acid, consequently great precautions must be taken to avoid leaky joints.

The Pictet compressor differs only slightly from the ammonia compressor, and the system appears more simple than the ammonia compressor system, because of the omission of oil separators and rectification apparatus.

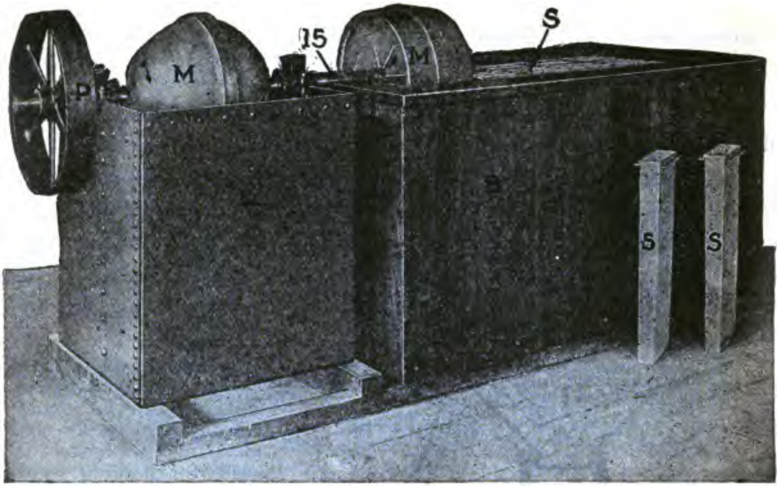


FIG. 5,571.—Audiffren anhydrous sulphur dioxide ice machine with brine transmission system. All the machinery is contained in a single rotor or "dumb-bell" which consists of two hollow bronze bells on a hollow shaft. This shaft revolves in two ordinary babbitt bearings and as it revolves one of the bells grows hot and the other cold. The cold bell revolves in the ice making tank B, and the hot bell in tank L of flowing water which constantly removes heat. As the cold bell continues to revolve in its tank of brine, the brine becomes very cold, so cold that a can of fresh water partly immersed in this brine will freeze into solid ice. The brine tank B is filled with rows of galvanized steel cans S, and the revolving cold end M chills the brine and also causes it to circulate through the rows of ice cans slowly freezing the fresh water inside the cans. The rotor M M is driven by any convenient power for the pulley P. ***Refrigeration:*** In cooling a refrigerator or cold room, brine is customarily circulated from the brine cabinet B, by a small pump, through the pipe coils in the refrigerator and returned to the brine cabinet. Except for the necessary piping the refrigerating unit differs in no way from the ice maker illustrated. The brine pump may be of any suitable type and the belt driven either from the main shaft of the machine or by a separate motor.

NOTE.—***Audiffren operating hints:*** Sufficient cooling water must always be flowing through the condenser tank L, when the machine is running. In case the water supply is cut off, the condenser will overheat, but no dangerous pressures can be generated. Should the condenser be permitted to rise over 90 or 95° F., the counterweight will turn over within the bell with a characteristic thumping noise. This is a signal to shut the machine down at once, as further operation may cause internal damage. The turnover, however, absolutely prevents further generation of pressure. To resume operation, it is necessary to cool the condenser to the lowest possible point, and start the machine. Low condenser temperatures result in greater heat absorption by the evaporator bell and less power to drive the machine. More heat will be absorbed at high brine temperatures than at low. ***In making ice,*** it is advantageous to harvest ice from a few cans several times a day, refilling the cans and replacing them in the brine. This prevents fluctuations of brine temperature and maintains a general high level. The brine should be kept strong, between 70° and 80° salanometer. Weak brine will freeze on the cold end M, and reduce the output of the machine, or stall the motor by rubbing on the hood. In making up brine allow it to cool thoroughly before starting machine. Allow only the ***rim*** of the cold end to dip in the brine until the temperature of the brine is 32° or lower. Then make up to the normal level—just below the bottom of the can rack. Scale forming on either bell must be periodically removed to prevent loss of efficiency. External babbitt bearings must be kept filled with machine oil. Machine must be level and not allowed to rub against tank wheels.

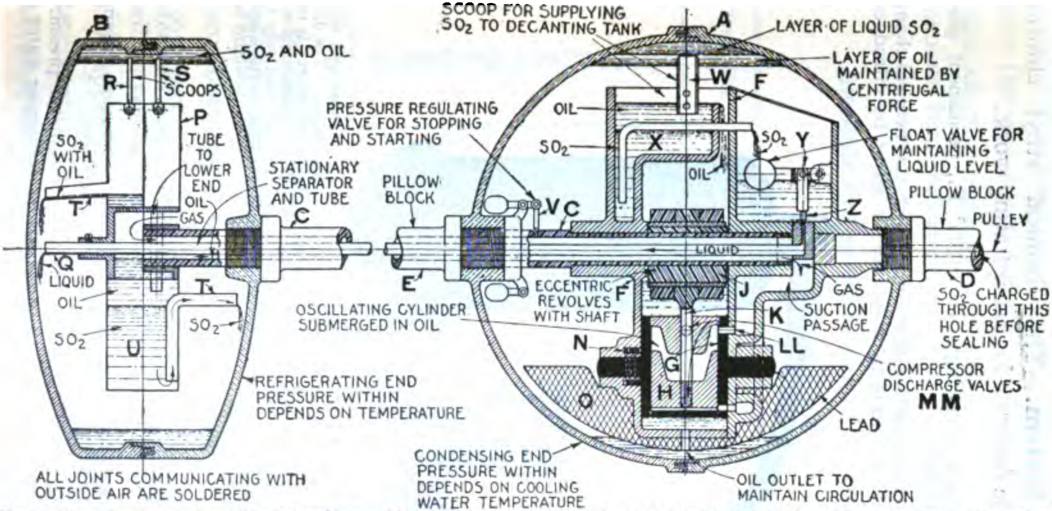

B
SO₂ AND OIL
R
S
SCOOPS
P
SO₂ WITH OIL
TUBE TO LOWER END
OIL
GAS
T
Q
LIQUID
OIL
SO₂
U
T
SO₂
STATIONARY SEPARATOR AND TUBE
C
PILLOW BLOCK
E
PRESSURE REGULATING VALVE FOR STOPPING AND STARTING
SCOOP FOR SUPPLYING SO₂ TO DECANTING TANK
A
LAYER OF LIQUID SO₂
LAYER OF OIL MAINTAINED BY CENTRIFUGAL FORCE
W
F
OIL
SO₂
X
OIL
SO₂
Y
FLOAT VALVE FOR MAINTAINING LIQUID LEVEL
V
C
Z
PILLOW BLOCK
PULLEY
LIQUID
ECCENTRIC REVOLVES WITH SHAFT
F
J
GAS
SUCTION PASSAGE
K
D
SO₂ CHARGED THROUGH THIS HOLE BEFORE SEALING
OSCILLATING CYLINDER SUBMERGED IN OIL
N
LL
G
H
O
COMPRESSOR DISCHARGE VALVES
MM
LEAD
REFRIGERATING END PRESSURE WITHIN DEPENDS ON TEMPERATURE
ALL JOINTS COMMUNICATING WITH OUTSIDE AIR ARE SOLDERED
CONDENSING END PRESSURE WITHIN DEPENDS ON COOLING WATER TEMPERATURE
OIL OUTLET TO MAINTAIN CIRCULATION

FIG. 5,572—.Sectional view of Audiffren ice machine showing mechanism. ***In construction,*** bells A and B, are hermetically sealed at all seams. Machine is charged at factory, after evacuation of air, with SO_2 and pure mineral oil. ***In operation,*** bells A and B revolve with hollow shafts D and EC. Carrier F is held stationary by counterweight O, the shaft revolving within it. Carrier supports two oscillating compressors G. Compressors are double acting and driven by eccentric F. Vapor is drawn by motion of piston H, through hollow shaft and port LL, into cylinder. Return stroke compresses vapor, expelling it through spring valves MM, into the surrounding space. Vapor condenses upon walls of A, and collects with surplus oil at rim. Scoop W, carries mixture to decanting box X, oil overflows over bearing surfaces, and liquid SO_2 is delivered to reservoir Y. Expansion valve admits liquid to central tube Q, which is stationary with carrier F. Liquid is delivered to interior of evaporator B, and expands again to vapor under suction of the compressors. Spent gas returns through hollow shaft. Separator V and P, collects surplus oil carried over with liquid SO_2 and returns it in the stream of spent gas, to the condenser end. There is no chemical action, and no deterioration of the gas or oil. When machine is stationary, pressure in both bells is equalized through valve V, which closes by centrifugal force, isolating the condenser from the evaporator when running. Power required to compress the gas is derived through the shaft and eccentric. Torque created is resisted by weight of carrier assembly and counterweight, which rises about 15° from vertical. Variation in condenser pressure (and temperature) and variation of evaporator pressure (and temperature) directly affect torque required. If either brine temperature or condenser temperature becomes excessive counterweight will revolve and readjust pressures automatically.

Ethyl Chloride System.—The chemical ethyl chloride (C_2H_5Cl) has desirable features for refrigerating work.

Its critical temperature being high, viz.: 365° F., permanent gases never form in the machine.

Having no chemical affinity with either air or water, no chemical change could take place should by accident either air or water be introduced into the machine.

FIGS. 5,573 to 5,575.—Clothel ethyl chloride refrigerant and lubricant container and filling hose. The ethyl chloride is put up in seamless drawn steel drums as shown. The drum and valve are tested to 300 lbs. hydrostatic pressure. A drop forged steel wrench is provided for operating the valve. The weight of the container and 50 lbs. of ethyl chloride is 89 lbs. The lubricant is chemically pure glycerine, it being important that only the chemically pure lubricant should be used with the system. It is furnished by the Clothel Co. under the trade name of "Clotheline." The cut also shows a can of the lubricant and filling hose for charging and draining the system.

It is a neutral chemical, consequently no corrosive action ever takes place. Copper can be used, if desirable, with soldered joints.

It is neither deleterious nor obnoxious, and, should occasion require, the engineer can work in its vapors without inconvenience.

The boiling point being high, viz.: 54.5° F., at atmospheric pressure, it liquefies at low pressure. In ordinary use with the condenser water at 65° F. the gauge pressure will be about 15 lbs. per sq. in.

The comparative table of pressures for various refrigerants, show the very moderate pressures of ethyl chloride which indicates an easy working cycle; with comparatively little loss of chemical from leakage around the stuffing box of the compressor.

Absolute Pressure Exerted by Various Refrigerants at Different Temperatures

Temp. Deg. Fahr.	Anhy. Ammonia.	Ethyl Chloride.	Carbon Dioxide.	Sulphur Dioxide.
0	30.8	4.1	314.5	10.3
5	34.2	4.7	335.0	11.9
10	38.3	5.4	362.8	13.4
15	42.9	6.1	391.7	15.3
20	48.0	6.9	422.5	17.1
25	53.4	7.8	455.7	19.4
30	59.4	8.7	490.0	21.6
35	65.9	9.7	526.2	24.3
40	73.0	10.8	565.2	27.0
45	80.7	12.0	607.2	30.1
50	89.0	13.3	650.0	33.4
55	97.9	14.8	696.7	37.0
60	107.6	16.3	745.0	41.0
65	118.1	18.0	795.5	45.2
70	129.2	19.9	849.3	49.7
75	141.2	22.0	906.5	54.6
80	154.1	24.2	967.0	59.9

The tables which follow giving the working pressures of ethyl chloride and vacuum and corresponding brine temperatures, have been made up (by the Clothel Co.) from averages taken from several installations under actual working conditions, and will vary slightly with different conditions; however, they give the approximate relations which should exist between the temperature of the condensing water and the pressure, and between the temperature of brine and the vacuum.

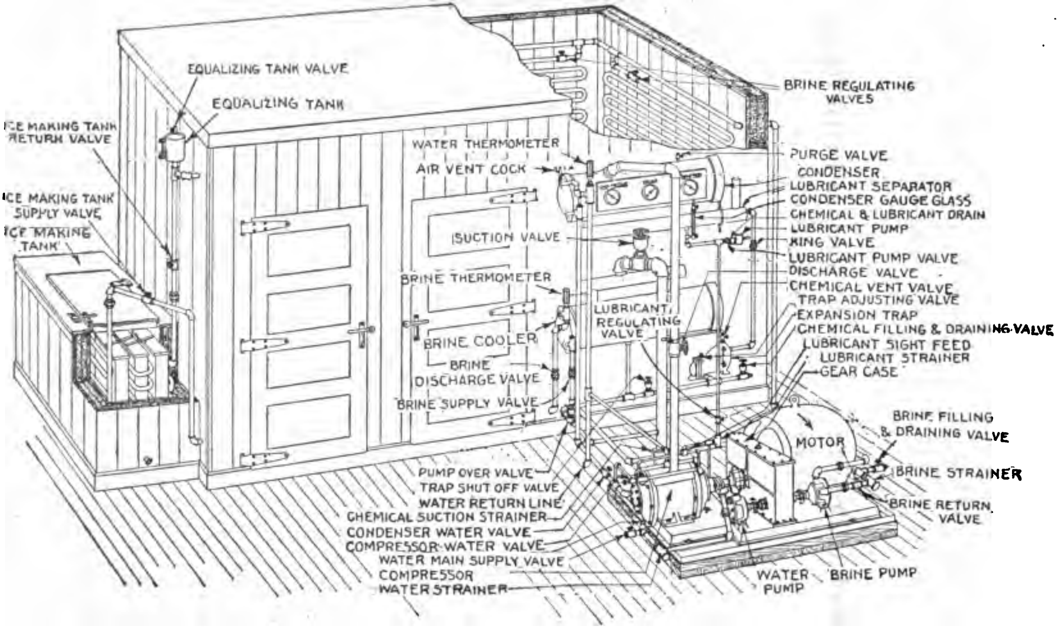


FIG. 5,576.—Typical installation of Clothel ethyl chloride system.

Working Pressure of Ethyl Chloride

Gauge pressure lbs.	Approximate temperature of outgoing condensing water
10	60°
15	71°
20	81°
25	91°
30	96°
35	106°

Vacuum and Corresponding Brine Temperatures

Inches vacuum	Approximate temperature of outgoing brine	Inches vacuum	Approximate temperature of outgoing brine
22	4°	14	31°
21	8°	13	34°
20	12°	12	36°
19	16°	11	39°
18	19°	10	41°
17	23°	9	43°
16	26°	8	46°
15	29°	7	48°

In the ethyl chloride system there is no direct relation between the temperature of the brine and pressure on the condenser, or between the vacuum on the machine and the pressure on the condenser. The pressure on the condenser varies in accordance with the temperature of the condensing water and the amount of the water used as in the table just given. The vacuum depends on the amount of work which the machine is doing, and this also regulates the temperature of the brine.

From the tabulation it will be noted that ethyl chloride is admirably adapted to refrigerating work in the tropics or in localities where the water available for condensing purposes has a high temperature or the supply is limited. At a temperature of 70° F. sulphur dioxide has a pressure of 49.7 pounds absolute, Anhydrous Ammonia 129.2 pounds absolute, carbon dioxide 849.3 pounds absolute and ethyl chloride only 19.9 pounds absolute which is a low pressure and safe to handle.

Ethyl chloride has been passed upon by the National Board of Fire Underwriters and by the United States Government for use on naval ships.

CO_2 System.—The chemical carbon dioxide, variously called carbonic-anhydride, carbonic acid gas or simply CO_2, and used as the refrigerant in this system, is made up of molecules containing one atom of carbon and two atoms of oxygen and has the chemical symbol CO_2. It is heavier than air, its specific gravity being 1.529, that of air being 1. Under atmospheric pressure it liquefies at a temperature of 124° below zero Fahrenheit.

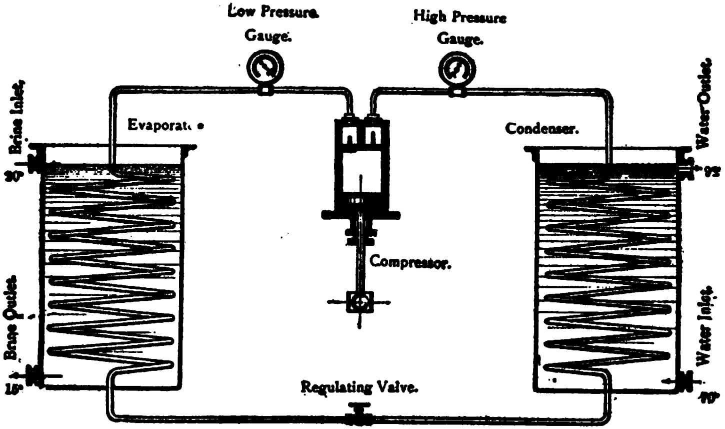


FIG. 5,577.—Carbonic acid system with brine circulation. ***It consists essentially of*** an evaporator, compressor and condenser. ***In operation,*** the heat required for evaporation is furnished by brine which surrounds the pipes, or by air. The gas, as it leaves the compressor passes into a separator where the glycerine impinges against the sides of the vessel and adheres to it as it has no affinity for carbonic acid; the glycerine then falls to the bottom of the separator and is drawn off from time to time, while the gas passes on into the condenser.

The boiling point of water being far above the atmospheric temperature, heat must be applied to bring it to the boiling temperature. The boiling point of liquid carbonic anhydride being much lower than the temperature of the atmosphere, it absorbs from its surroundings the necessary heat to cause it to boil or evaporate.

Commercial carbonic anhydride is manufactured from coke, magnesite, etc. Formerly large quantities of commercial gas were obtained from the fermenting tubs in breweries. After being liquefied under high pressure the gas is charged into steel drums of either 20 lbs. or 50 lbs. capacity and it is then ready to be placed on the market. Carbonic gas is extensively used for carbonating beverages.

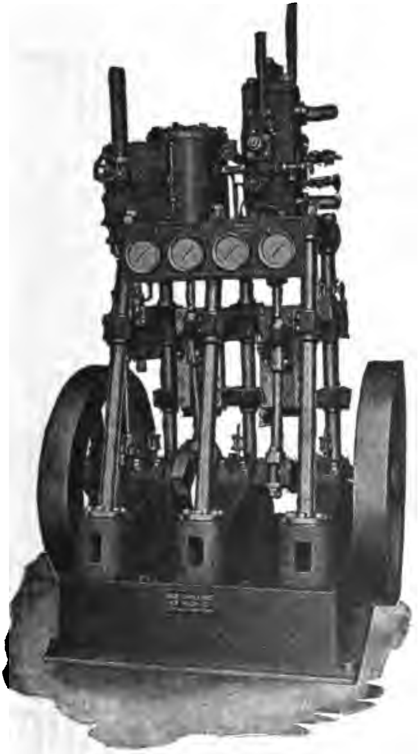


FIG. 5,578.—Kroeschell vertical double-acting steam marine type carbonic anhydride (CO_2) compressor. ***In construction,*** **the cylinders are cast in a solid block, the bore, valve chambers and valve ports being machined in the block. As the entire cylinder is made in one piece, and all valves are placed directly in the cylinder, there are no joints in the bore over which the piston must travel. The discharge pressure in the cylinder varies from 50 to 80 atmospheres depending upon the requirements. A safety valve is placed in the high pressure channel between the discharge valves and the discharge stop valve. The purpose of this valve is two fold. It will relieve the cylinder, also the refrigerating system, of a pressure that has risen above the normal, in case of fire or through lack of condenser water, and it will also guard against carelessness of the operator were he to start the compressor in operation without first opening the discharge stop valve. As the opening of the safety valve is accompanied by a loud report, it will direct the attention of the operator to the compressor. When the excess pressure has been relieved and the pressure in the cylinder again becomes normal, the safety valve closes automatically. The safety valve is designed to blow off at a pressure considerably below that to which the compressor and other refrigerating equipment has been tested.**

Carbonic anhydride is neutral toward food products and all other materials. It is odorless, non-explosive, non-inflammable

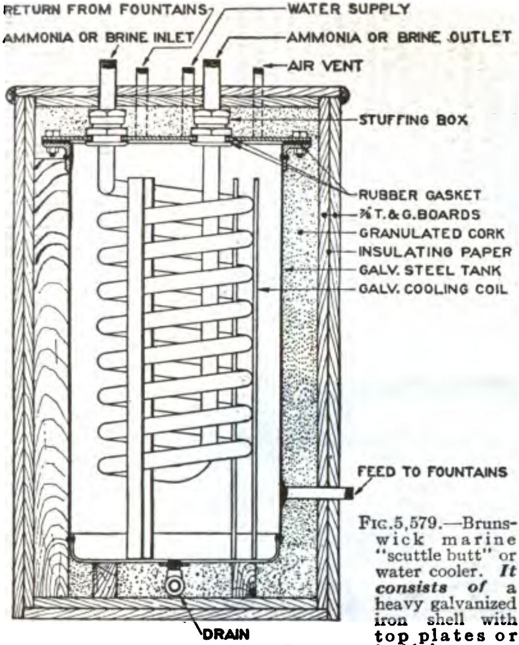


FIG. 5,579.—Brunswick marine "scuttle butt" or water cooler. *It consists of* a heavy galvanized iron shell with top plates or covers bolted securely in place. The galvanized brine or ammonia coil extends through the top of the tank, being secured by special bulkhead connections.

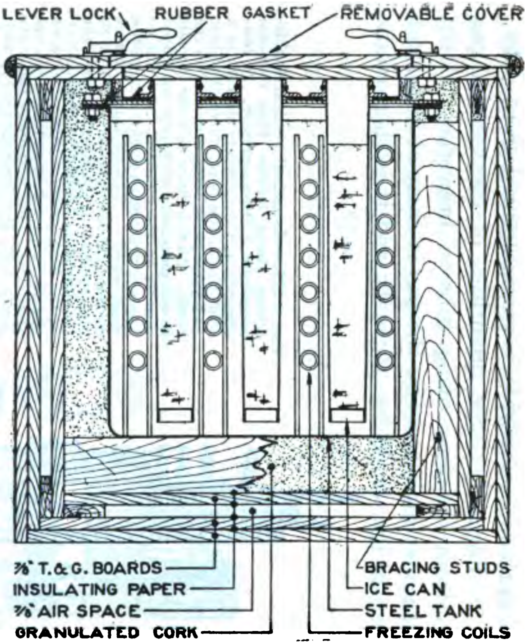


FIG. 5,580.—Brunswick marine ice making set. *It consists of* a heavily insulated steel tank, with steel cover in which openings for the ice cans are cut. A heavy flange on the cans; a rubber gasket between the can flanges and the top of the tank, and special covers clamped down securely to the top of the tank prevent either the brine in the tank or the water in the cans slopping out, even in the roughest seas. The most generally used sizes for freighters and the smaller passenger ships are the 120-lb., 180-lb. and 240-lb. sets 10 to 12-hour rating. The larger passenger ships may require a greater amount of ice—500 to 1,000 lbs. or more. The smaller sets are usually equipped with 20-lb. ice cans; larger ones with 50-lb. ice cans.

and cannot become a source of danger to life or property. Unlike other refrigerants it does not become a menace in time of fire, instead it is a fire extinguisher.

Carbonic anhydride is supplied in steel cylinders and can be procured almost anywhere at a cost of a few cents per lb.

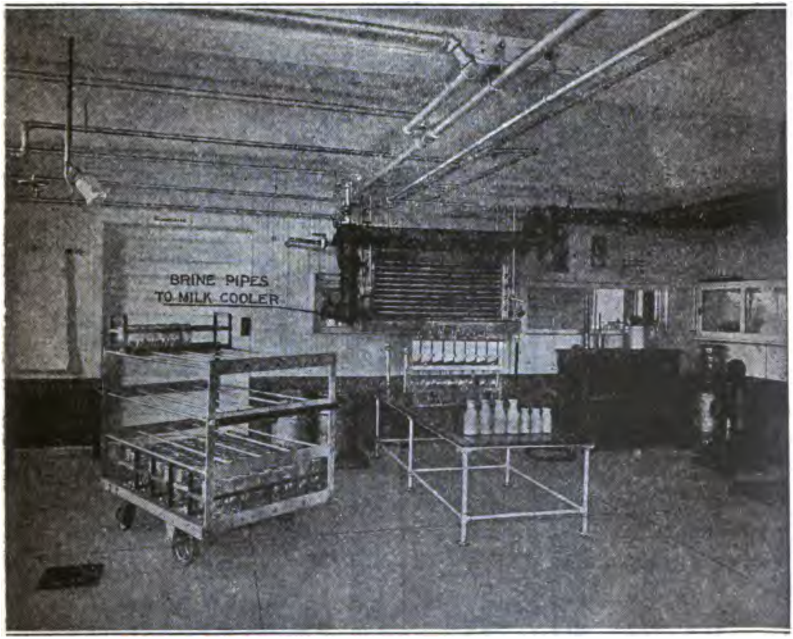


Fig. 5,581.—Brunswick application of mechanical refrigeration to modern dairy work. In this plant the compressor is connected to a combined ice making and brine cooling tank and storage refrigerator.

Ether System.—This method of refrigeration has never come into extensive use owing to the relatively large compressor necessary, but more especially to the inflammability of ether and the great liability to explosion. The great advantage of ether is that it requires only a low pressure in the condenser, which is of no little importance in warm climates, and which has led to its use by the British military authorities in several campaigns in Africa. The low pressure is also favorable for the maintenance of tight joints, and the simplicity of the working parts. Another important fact in connection with military operations is that as ether

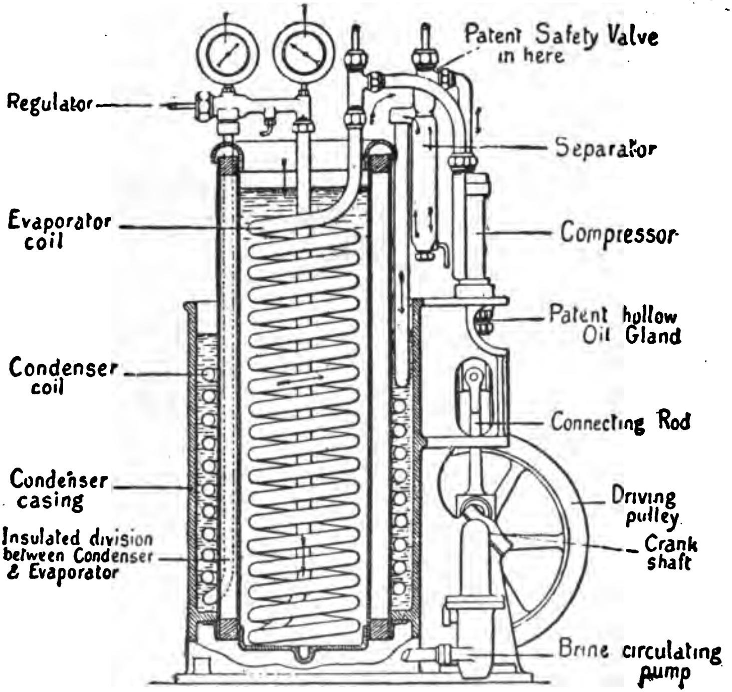


FIG. 5,582.—Hall marine carbonic acid refrigerating machine. The compressor is directly attached to the body of the condenser which is of the submerged type. The cooler consists of a shell concentric with the condenser, well insulated from same, and containing the evaporating coil. The condenser coil connects with the evaporator coil through the expansion valve shown at the top within easy reach, and each coil is provided with a pressure gauge, the one at the right being the low pressure and at the left, the high pressure gauge. The brine is circulated through the cooler by means of a small brine pump attached to the crank shaft.

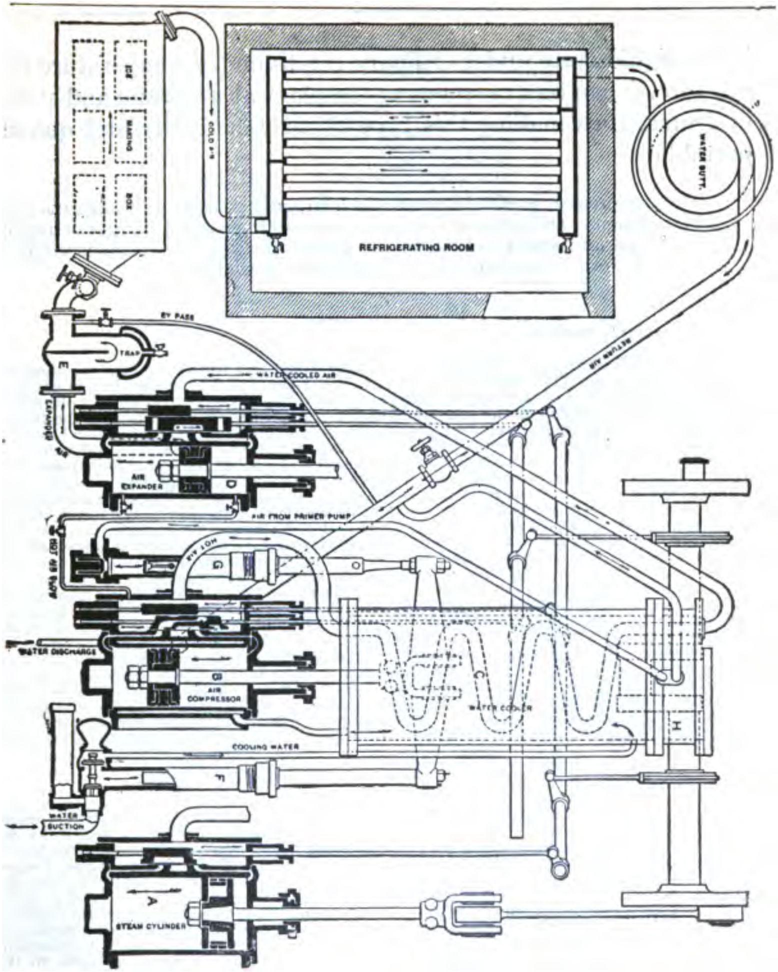


Fig. 5,583. Diagrammatic plan view of Allen dense air machine. The following are the important parts: A, The steam cylinder which furnishes the power to its crank shaft, to which the air compressor and the expander are linked. The letters refer to the opposite diagram. B, The air compressor cylinder which compresses the air to about three times the entering pressure. As this causes the air to heat, the cylinder is surrounded by a water jacket to make lubrication practicable. The compression cylinder is constructed with slide valves, instead of the usual conical lift valves, in order to move more quickly and noiselessly. C, a copper coil in a bath of water; the compressed hot air in passing through it cools to the is in a liquid state under ordinary conditions of temperature and pressure, it can be drawn out of the plant at any time and stored in drums, thus making this type of machine easily and quickly portable.

The compressor required is very much larger than in an ammonia machine of like capacity, and its generally massive construction, and larger consumption of coal and water, added to the great fire risk, have seriously handicapped the ether machine for ordinary commercial use.

FIG. 5,583.—*Text continued.*

temperature of the water. The return air cooler which still further reduces the temperature of the air. D, The expansion cylinder, to which the cooled compressed air is admitted until it fills one-third of the volume of the cylinder. The air supply is then cut off, and as the piston makes its full stroke to the end of the cylinder the air expands until the tension is about normal, and the expansion cools the air about as much as the compression heated it. It is constructed like a usual steam engine cylinder, with slide valve and cut off valve. It must cut off the pressure at such a point that the expanded air at the end of the stroke oi the piston is very nearly of the same pressure as the air contained in the system of pipes. If it were of much higher pressure it would, at exhausting, warm up again, by exerting its remaining power in producing velocities and frictions inside of the apparatus. The air, therefore, leaves this cylinder at a very low temperature and is discharged into a well insulated pipe which conveys it to the point of use; there the pipe is exposed and the cooling is effected, the air returning to be used over. The expander helps the steam cylinder and the air compressor takes the power. E, is a trap placed just after the expander which intercepts any oil and snow; the trap is provided with a heating pipe and the contents of the trap should be drawn off every few hours. The machine is so arranged that at the same time any frozen deposits in the expander cylinder can be thawed and blown into the trap. F, is the water pump which circulates water around the copper coil C, and through a water jacket which surrounds the working cylinder of the air compressor B, in order to prevent the heat injuring the packings. G, is a small air compressing pump which takes air from the atmosphere and pushes it into the machine and pipe system. This charges the system with the requisite air pressure when the machine starts to work, and maintains the pressure against leakages occurring at the stuffing boxes and joints. This air, of course, contains the usual atmospheric moisture, and to expel this, the outlet pipe from this pump passes the air through the trap H.

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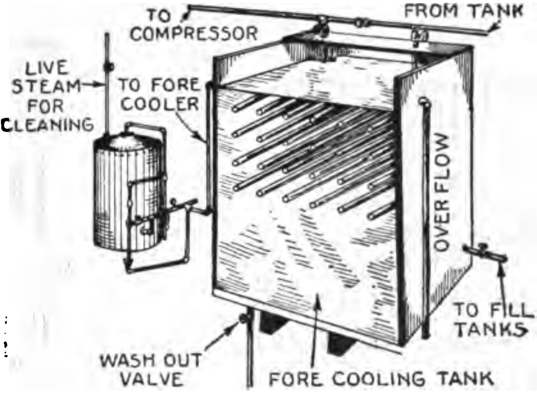
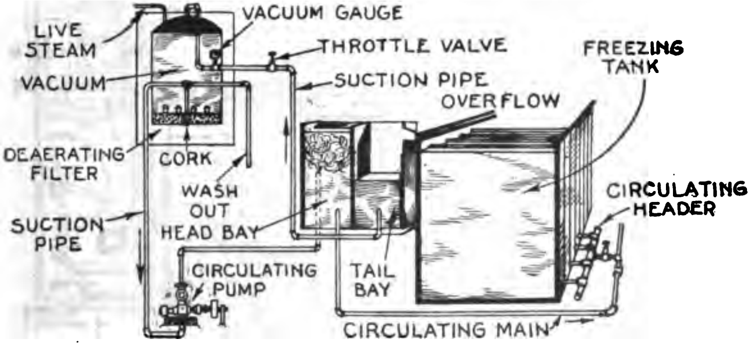
*NOTE.—In the ***Allen dense air*** machine, where the same air is used over and over again, additional moisture can only come from the small make up air supply, and most of this is removed by the trap provided for this purpose. ***In operation*** this trap should be watched in order to make sure that its action is efficient and that there is no danger of the passage of water over into the expansion system. In routine operation it is usually desirable to clean the machine by heating it up and blowing out all the oil and ice deposits. To this end the valves in the main pipes leading the air to and from the coils are closed, thus shutting off the machine from the remainder of the system. A by pass is then opened, connecting the main expansion pipe beyond the oil and snow trap with the main return from the coils. Connections are then opened in the so called hot air pipe leading from the compressor cylinder to the expansion cylinder, and the expansion inlet valve is partly closed. Live steam is then let slowly into the jacket of the oil trap in order to thaw out all ice and hardened oil, and the machine is run moderately for at time, during which the blow off valves of the trap and expansion cylinder are frequently opened until everything appears clean. Then the machine is readjusted to its normal condition and run as before. If it should be suspected that any considerable quantity of oil and water have gotten into the pipe system and are clogging the surfaces, the pipes may be cleaned by running hot air through them and drawing off the oil and water at the bottom of the manifolds of the refrigerating coils.





Figs. 5,584 and 5,585.—Prime filter and fore cooler, and apparatus for circulation and deaeration for dry plates. ***In operating*** it (fig. 5,584), water enters the prime filter (to which a live steam pipe is connected for cleaning), and afterwards passes to the covered fore cooler where its temperature is reduced to about 40 degrees by the ammonia coils. The overflow from this cooler is shown at the right and it discharges into the tailway marked "overflow" in fig. 5,585 and from it falls into the tail bay. A suction pipe takes it from this point and discharges it into the vacuum chamber, where it passes downward through cork and thence through the suction pipe to the pump. It will be noticed that in this suction pipe there is a throttle valve, and by partially closing this, any required degree of vacuum may be obtained, which will be indicated by the gauge. Now, the effect on the water caused by slowly passing it through a filter bed under a vacuum, is to separate the air from the water, and although it remains in contact with it, still the water does not again absorb the air, but when the whole is discharged into the head bay, the air rises to the top, as shown, while the deaerated water goes to the bottom and passes out through the circulating main to the circulating header, where it is delivered to the several sections to be frozen into plates, for this is known as the dry plate system. Up to this point the block and the dry plate systems are identical.

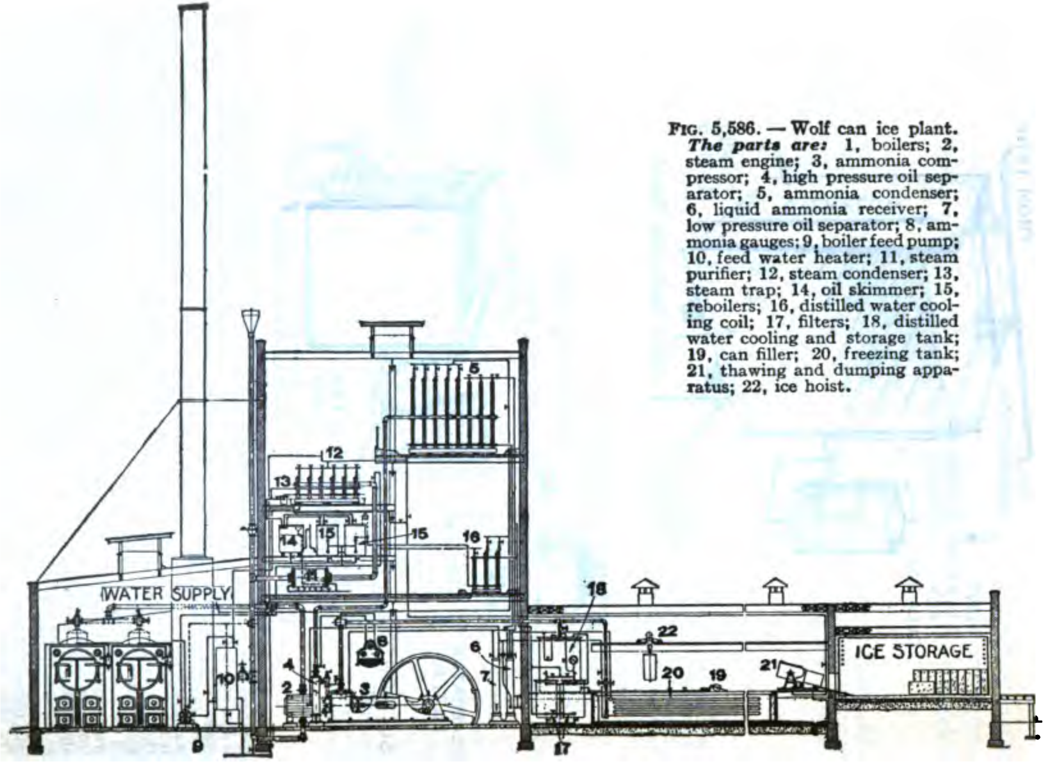


FIG. 5,586. — Wolf can ice plant. ***The parts are:*** 1, boilers; 2, steam engine; 3, ammonia compressor; 4, high pressure oil separator; 5, ammonia condenser; 6, liquid ammonia receiver; 7, low pressure oil separator; 8, ammonia gauges; 9, boiler feed pump; 10, feed water heater; 11, steam purifier; 12, steam condenser; 13, steam trap; 14, oil skimmer; 15, reboilers; 16, distilled water cooling coil; 17, filters; 18, distilled water cooling and storage tank; 19, can filler; 20, freezing tank; 21, thawing and dumping apparatus; 22, ice hoist.

Mechanical Ice Making.—The term "mechanical ice making" as here used relates to the apparatus and methods employed in freezing ice into cakes for distribution by ice wagons. There are two methods known as

1. The can method;
2. The plate method,

the former being the more extensively used.

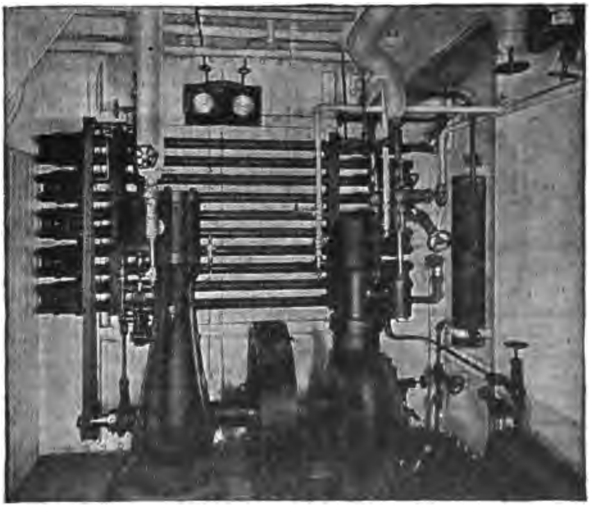


FIG. 5,587.—Brunswick two ton marine refrigeration plant. The machine here shown cools the refrigerator for the ship's stores, which is divided into several compartments, for meats, vegetables, dairy supplies, etc., besides making sufficient ice for table use and cooling two "scuttle butts" or water coolers located at convenient points. The outfit, including compressor, engine, condenser, liquid receiver, oil separator, and connecting piping fittings, etc., is installed in a space of 6 X 8 feet.

Ques. Describe the can method.

Ans. Galvanized cans or moulds are filled with water, after they have been suspended the proper depth in a tank of brine, the brine being cooled by a direct expansion system in the freezing tank.

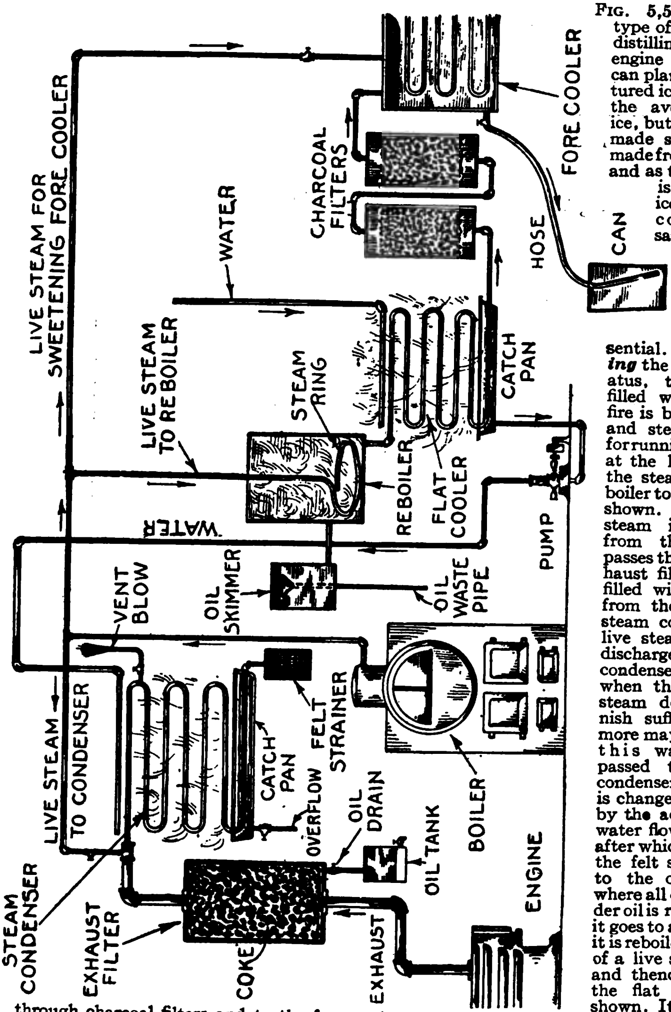


FIG. 5,588. — General type of apparatus for distilling water from engine exhaust for a can plant. Manufactured ice is purer than the average natural ice, but it can only be made so when it is made from pure water, and as the water that is put into the ice plant may contain the same impurities that any other water does, special apparatus for purifying it is essential. ***In operating*** the above apparatus, the boiler is filled with water, a fire is built under it, and steam is raised for running the engine at the left, although the steam pipe from boiler to engine is not shown. After the steam is exhausted from the engine it passes through the exhaust filter, which is filled with coke and from thence into the steam condenser. A live steam pipe also discharges into this condenser, so that when the exhaust steam does not furnish sufficient water more may be added in this way. Having passed through the condenser the steam is changed into water by the action of cold water flowing over it, after which it goes to the felt strainer and to the oil skimmer where all of the cylinder oil is removed and it goes to a tank where it is reboiled by means of a live steam pipe, and thence passes to the flat cooler as shown. It then passes through charcoal filters and to the fore cooler and when it comes out of the faucet and goes through the hose to the can, it certainly may be considered clean.

The time required for freezing varies from 40 to 60 hours, depending on the thickness of the cakes. The longer the time a given thickness is allowed to freeze the better the quality.

In removing the cakes from the cans, the cans are drawn out of the brine and sprayed with, or dipped into, warm water which loosens the ice so that when the can is inclined on its side the cake of ice slides out, the can being made tapering in shape so as to facilitate the movement.

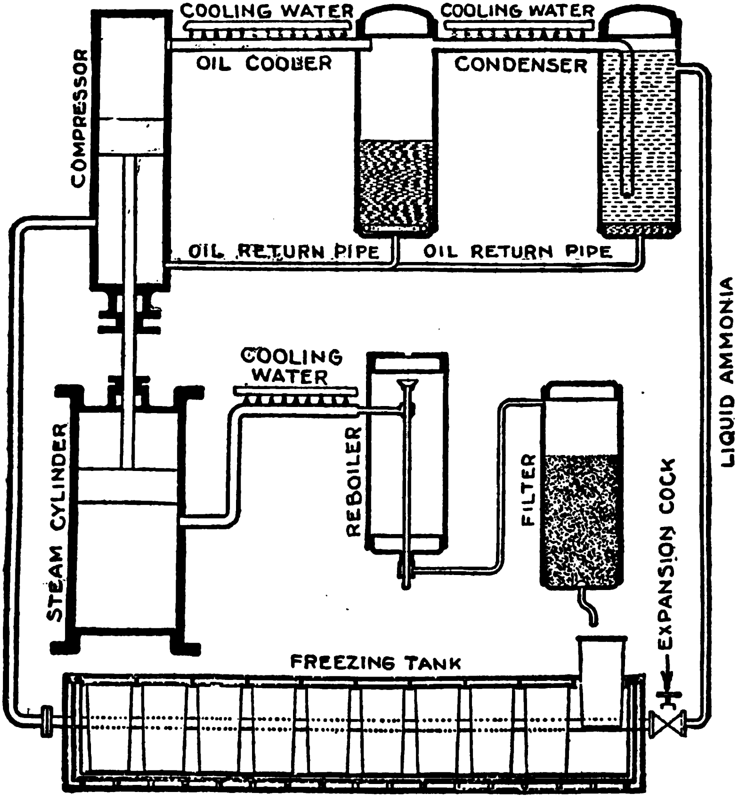


FIG. 5,589.—Diagram of De La Vergne ice making plant showing the distilling system and freezing tank.

One man with a hoist can handle from ten to fifteen cans per hour.

The cans are filled with a can filler which is so constructed as to automatically shut off the water supply when the can is filled to the proper height. The filler is inserted in the can and the water turned on. As the can fills the ball floats and rises until the can is filled to the right depth, when the valve is automatically closed.

The depth at which the brine is carried in the freezing tanks is an important feature in obtaining the quantity of ice the machine is capable of making. The brine should come as close to the top of the can as possible, and should be somewhat higher than the water in the can, since allowance for expansion as the water freezes is made when the cans are filled. Cans

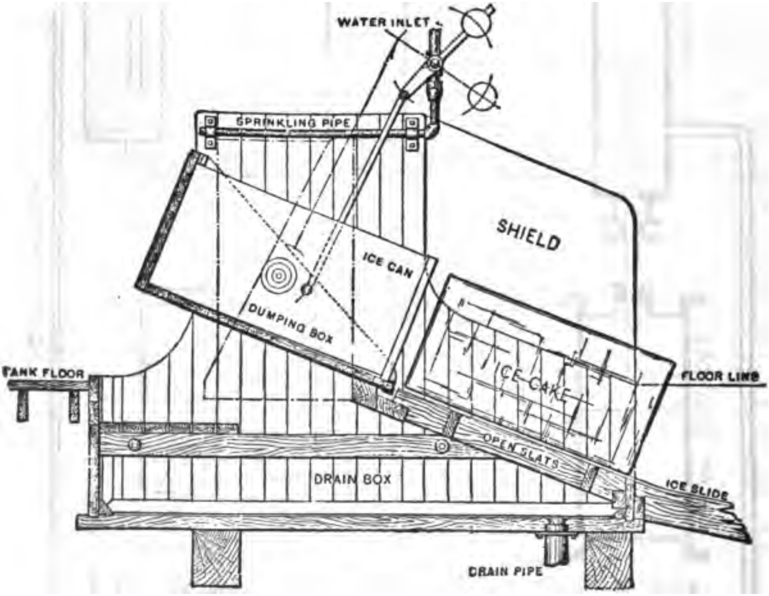


FIG. 5,590.—Sectional view of a can dumper. The dumping box is connected by a link to the valve in the sprinkling pipe, thus as soon as the box is turned into the position shown the valve automatically opens, and hot water is sprinkled over the can and the cake of ice is thus loosened.

NOTE.—The cloudy or milky appearance of an ice cake is due to the presence of air. This may be due to deficient re-boiling, the overworking of the re-boiler, or more likely than either, to an insufficient supply of steam to the distilled water condenser, in which case the rapid condensation of the steam causes a vacuum and air is drawn in.

that are properly filled with water will be even full of ice when frozen. It may take some experimenting to find the exact quantity of water required, but the time and trouble will be more than paid for in the increased yield of ice.

A red core which is occasionally seen is due to the presence of carbonate of iron which may come from scale on the pipes and which impregnates the steam, thence appearing in the center of the ice cake.

Ques. Describe the plate method.

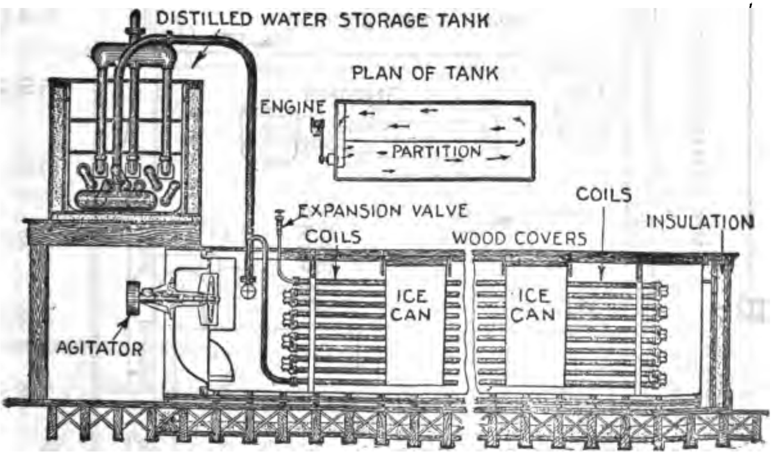


FIG. 5,591.—Detail of freezing tank of an Eclipse ice plant, showing the arrangement of the cans with covers, also the brine agitator. The agitator is in the shape of a propeller which keeps up a continuous circulation of brine between bottom and top of tank.

Ans. Several vertical hollow iron walls are built in a large tank. The tank is filled with pure well water so that the iron walls are entirely submerged. The hollow iron walls are placed parallel to each other at a distance of from two to three feet. The freezing fluid, consisting either of cold brine or ammonia, is passed through the hollow walls, with the result that the water will freeze on the outside of the walls; the water is kept in agitation either by means of a propeller or pump, or by compressed

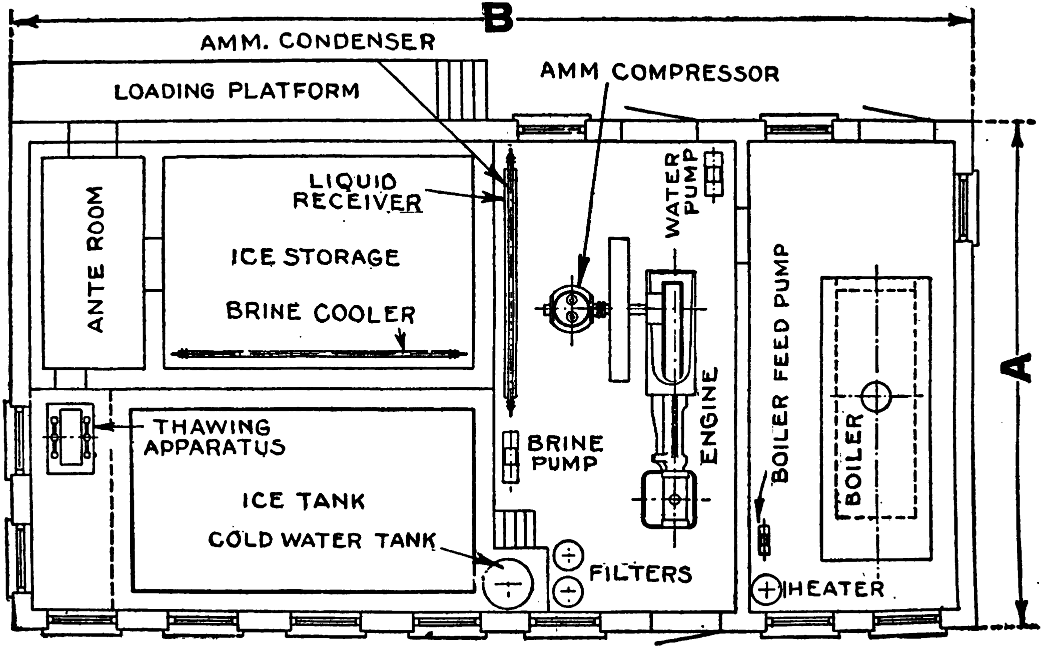
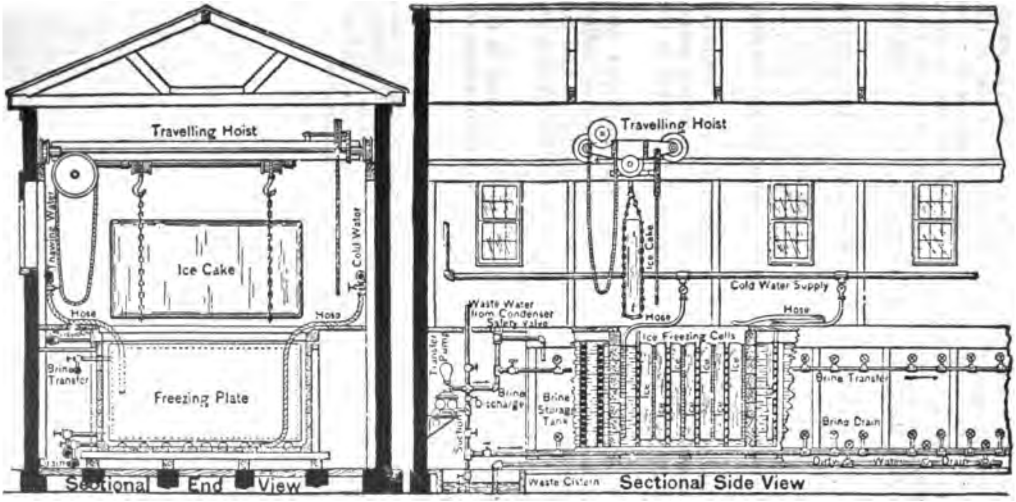


FIG. 5,592.—Ground plan of ice factory giving approximate dimensions for different capacities.

Capacity in tons..........	3	5	10	15	20	25	30	35	40	50
Dimensions at **A** in feet...	25	28	32	35	38	40	40	40	48	48
Dimensions at **B** in feet...	50	60	70	75	82	90	100	115	120	130



FIGS. 5,593 and 5,594.—Eclipse plate ice plant showing sectional view of freezing cells. The ice plates are hoisted by means of the traveling hoist after being thawed off the freezing plates by passing hot brine through the coils. The freezing plates with their coils are shown in heavy black lines with the ice forming on both sides of them.

air, so that the water is kept continually on the move; carrying the air with it prevents it being frozen in the ice. After the ice is frozen on the walls to the required thickness the freezing fluid is shut off from the walls and a warm fluid passed through instead until the ice is loosened and taken out of the tank.

The construction of the plate walls differs according to the freezing fluid used. If cold brine be used, then the brine has to be cooled in a separate refrigerator from which it is pumped through the walls and back to the refrigerator, the same as is done when cooling rooms by means of brine pipes. The plate walls in such a case are generally constructed of iron. On account of the expansion and contraction occasioned by warm or cold brine being passed alternately through the hollow walls, it is very difficult to keep them tight.

If ammonia gas be used, the walls are built up of expansion pipes, which, connected at each end by return bends, make one continuous zig-zag coil. To get an even surface the coils are covered with thin iron plates on the outside of which the ice is frozen. Loosening the ice, when thick enough, is effected by shutting off the cold ammonia gas and passing hot gas through the pipes instead.

Agitation of the water in the plate method is accomplished by means of air jets located midway between the plates, sometimes in the center, sometimes three or four feet from one end and sometimes at both ends of the plates.

The harvesting of plate ice is similar to the methods employed with can ice, excepting that in use for harvesting block ice. Some use hollow lifting rods and thaw them out with steam, others use solid rods and cut them out when cutting up the ice, and others again use chains which are slipped around the cake when it floats up in the tank.

The advantage of plate ice over can ice is that, since the water is not confined in a can, it will freeze clear, and for this reason it is not necessary to distill the water, it only being necessary to filter it.

NOTE.—To pass at one time cold and at another time hot ammonia gas through the same pipes can only be done by bringing the pipe walls alternately in connection with the expansion and the compression side of a refrigerating machine, that is to say, make the pipe walls act at one time as a freezer and at another as a condenser. To do this special valve connections have to be made, which are complicated, and (to avoid accidents) require careful handling.

CHAPTER 85

CONDENSERS

In order to understand the operation of condensers, it is first necessary to know the meaning of the term *vacuum*. By definition a vacuum is *a space void of matter*, a condition regarded as practically impossible in nature, hence, by erroneous use and for convenience, the term vacuum has come to mean *an enclosed space from which the air (or other gas) has been very nearly removed, as by an air pump*—this is, strictly speaking, a *partial vacuum*, or an enclosed space in which the pressure is less than that of the atmosphere and greater than absolute zero.*

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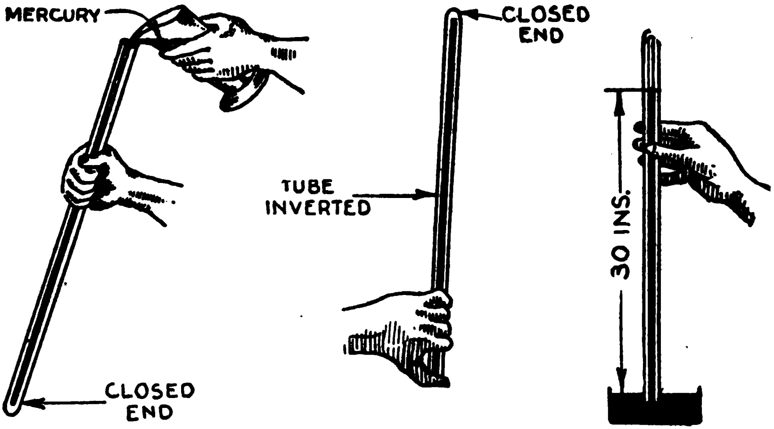
*NOTE.—According to the Century Dictionary, metaphysicians of Elea, Parmenides and Melissus started the notion that a vacuum was impossible, and this became a favorite doctrine with *Aristotle*. All the scholastics upheld the maxim that "*nature abhors a vacuum*." This is the doctrine of the plenists. Atomism, on the other hand, carried out in a thoroughgoing manner, supposes empty space between the atoms. That gases do not fill space homogeneously is now demonstrated by the phenomena of transfusion and by the impulsion of Crookes's radiometer; while the other observed facts about gases, taken in connection with these, render some form of the kinetical theory of gases almost certain. This supposes the molecules of gases to be at great distances from one another as compared with their spheres of sensible action. This, however, does not exclude, but rather favors, Boscovich's theory of atoms, namely, that atoms are mere movable centers of potential energy endowed with inertia; and this theory makes each atom throughout all space in a certain sense. But this does not constitute a plenum, for a plenum is *the exclusive occupation of each part of space by a portion of matter*. It may be said that the spaces between the atoms are filled by the luminiferous ether, which seems to be the substance of electricity, but the dispersion of light by refraction seems to show that the ether itself has a molecular structure. A vacuum, in the sense of a space devoid of ordinary ponderable matter, is produced (more or less perfectly) when the air is removed from an enclosed space, such as the receiver of an air pump, a part of a barometric tube, etc. In the receiver of the ordinary air pump the vacuum can only be partial, since with each stroke of the piston only a certain fraction of the air is removed (depending upon the relative size of the cylinder and the receiver), and hence, theoretically, an infinite number of strokes would be necessary. ***Practically, the degree of exhaustion obtained falls short of that demanded by the theory***, owing to the imperfections of the machine; thus, in the common form, the exhaustion is limited to the point where the remaining air ***has not sufficient elasticity to raise the valves***. By the Sprengel or mercury air pump a nearer perfect degree of exhaustion is attainable than with the mechanical form. The nearest approach to a perfect vacuum is obtained when chemical means are employed to absorb the last traces of gas left is exhausted by mercury air pump. ***The Torricellian vacuum*** —that is, the space above the mercury in a carefully manipulated barometer tube, is more nearly perfect in this respect, but the space contains a small amount of the vapor of mercury.

At sea level the pressure of the atmosphere is ordinarily 14.7 lbs. per sq. in., measured above absolute zero, that is, the zero pressure of a perfect vacuum. The atmospheric pressure gradually decreases with increasing elevation. For instance, at ¼ mile above sea level it is 14.02 lbs.; at ½ mile, 13.33; at ¾ mile, 12.66; at 1 mile, 12.02; at 1¼ miles, 11.42, at 1½ miles, 10.88, and at 2 miles, 9.8 lbs. per sq. in. For a rough approximation, the pressure is said to decrease ½ lb. for each 1,000 ft. of ascent.

At any given point the atmospheric pressure is continually varying, being influenced by weather conditions.

To measure the pressure of the atmosphere, take a glass tube about three feet long, closed at one end, and fill it with mercury as in fig. 5,595, close the open end with the thumb to prevent premature escape, and invert it, as in fig. 5,596, and placing the open end in a cup of mercury, as in fig. 5,597.

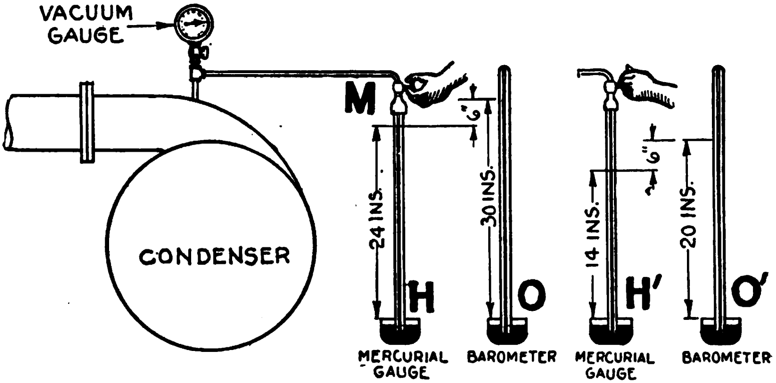


FIGS. 5,595 to 5,597.—Measuring the pressure of the atmosphere with mercury column. Take a 3 foot glass tube closed at one end, fill it with mercury as in fig. 5,595, invert as in fig. 5,596, and submerge the open end in a cup of mercury as in fig. 5,597. The column of mercury will fall in the tube until its weight is just balanced by the pressure of the atmosphere, thus indicating "*in inches*" the pressure of the atmosphere. The device as shown in fig. 5,597 is called a barometer.

When the thumb is removed from the open end of the glass tube the mercury inside will recede from the closed end of the tube until the column stands approximately 30 ins. above the level of the mercury in the cup, and since a cu. in. of mercury weighs .4916 lbs., the pressure of the atmosphere when the mercury column stands 30 ins. high, is

$$.4916 \times 30 = 14.74 \text{ lbs. per sq. in.}$$

Now if the end of the barometer, instead of being closed, were put in communication with the inside of a condenser the mercury would fall in the tube until its height indicated ***the difference between the atmospheric pressure and the pressure in the condenser.*** Thus, in fig. 5,598 the barometer



Figs. 5,598 and 5,599.—The meaning of a 24 inch vacuum "referred to a 30 inch barometer." According to the vacuum gauge the condenser here shown is operating under a 24 inch vacuum. This means that if a glass tube H, whose lower end is submerged in a cup of mercury, have its upper end connected to a branch pipe leading to the condenser, on opening valve M, the mercury will be "sucked up" in the tube to a height of 24 inches above the level of the mercury in the cup. Strictly speaking it is not correct to say "sucked up," because the mercury is in reality "pushed up" by the weight of the atmosphere which presses downward against the exposed surface of the mercury outside of the tube. Opposing this pressure is a back pressure in the condenser equivalent to 6 ins. of mercury, hence the mercury in H, glass stands at only 24 ins., instead of at 30 ins. as in the barometer O, where there is no back pressure opposing the pressure of the atmosphere. Now evidently the condition of 24 inch vacuum with 6 inch back pressure in the condenser can only exist when the barometer stands at 30 inches as explained in the text, that is

$$\begin{array}{ccccc} \text{vacuum} & + & \text{condenser pressure} & = & \text{atmospheric pressure} \\ 24 & + & 6 & = & 30 \end{array}$$

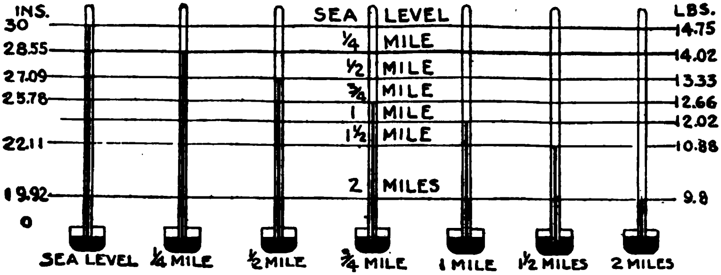
Accordingly the 24-inch vacuum, in the condenser, is said to be "*referred to a* 30 *inch barometer*," because with the constant condenser pressure of 6 ins., the column of mercury H, will only remain at 24 ins. as long as the barometer O, is at 30 ins., varying in height with O, being always 6 ins. less than O. Thus if the barometer drop to say 20 ins. as in O′, fig. 5,599 the vacuum in the condenser would also drop to 20—6 = 14 ins. as in H′.

O, which registers the pressure of the atmosphere stands at 30 ins. If a similar tube H, be submerged in a mercury cup and its upper end connected to a condenser as shown, if there be say a 24-inch vacuum in the condenser, on opening valve M, the mercury will be "sucked up" in the tube to a height of 24 inches or six inches less than the height of the barometer O. The 6 ins. difference between the two columns represents the *absolute pressure* in the condenser, that is

absolute pressure in condenser = 6 × .49116 = 2.95 lbs. per sq. in.

The 24-in. vacuum in the condenser is the difference between the atmospheric pressure (14.74 lbs.) and the absolute pressure (2.95 lbs.) in the condenser, that is

24-inch vacuum in condenser = 14.74—2.95 = 11.79 lbs. per sq. in.

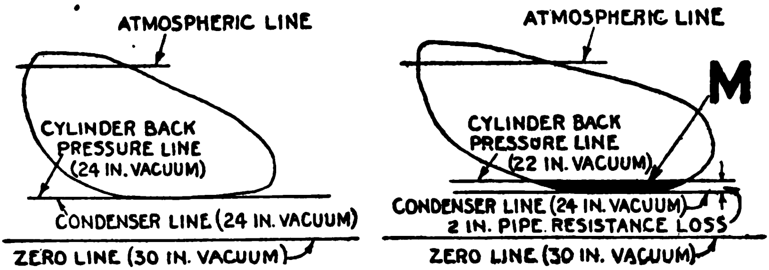


FIGS. 5,600 to 5,606.—Readings of the barometer in ins. of mercury with equivalents in lbs. per sq. inch for different elevations. It should be noted that although ordinarily the atmospheric pressure at sea level is taken at 30 ins. corresponding to 30 × .49116 = 14.74 lbs. per sq. in., or roughly 14.7 lbs., there is a ***standard atmosphere*** which as taken by ***Marks and Davis*** in their steam tables is defined as 29.921 inches of mercury or 14.696 lbs. per sq. in.

Now, what would happen if the apparatus shown in fig. 5,598 were raised to a high elevation, causing the mercury in the barometer tube O, to fall to say 20 ins. as in O′, fig. 5,599? Evidently, at this high elevation a 24-inch vacuum could not exist in the condenser, but the absolute 6-inch back pressure in the condenser would remain the same, hence the mercury in the mercury gauge would fall to 20—6 = 14 ins. as in H′, fig. 5,599.

If an engine be attached to the condenser shown in fig. 5,598 and there was no drop in pressure between the cylinder and the condenser, the working conditions would be represented by the card, fig. 5,607. Note here that the exhaust line of the card coincides with the condenser line corresponding to the 24-inch vacuum, which exists in the condenser. In practice this is not possible because the exhaust or back pressure in the cylinder will always be greater than the condenser pressure on account of the frictional resistance due to the exhaust pipe, elbows, cylinder passages, etc., giving some such card as in fig. 5,608. Note here that the cylinder back pressure line is is *higher* than the condenser line resulting in a card loss represented by the solid black area M.

Saving Due to Condensing.—When an engine is run without a condenser the steam must be exhausted against the pressure of the atmosphere, or 14.7 lbs per. sq. in. Now the nature of steam is such that most of this back pressure can be removed, that is, if at the end of the forward or steam admission stroke, the cylinder full of steam be chilled as by injecting cold water


ATMOSPHERIC LINE
CYLINDER BACK PRESSURE LINE (24 IN. VACUUM)
CONDENSER LINE (24 IN. VACUUM)
ZERO LINE (30 IN. VACUUM)
ATMOSPHERIC LINE
M
CYLINDER BACK PRESSURE LINE (22 IN. VACUUM)
CONDENSER LINE (24 IN. VACUUM)
2 IN. PIPE. RESISTANCE LOSS
ZERO LINE (30 IN. VACUUM)

FIGS. 5,607 and 5,608.—Indicator cards showing theoretical and actual operation of an engine connected to the condenser shown in fig. 5,598, with respect to exhaust or back pressure. In order to magnify the pressure scale *l.p.cyl.* cards of a compound engine are shown.

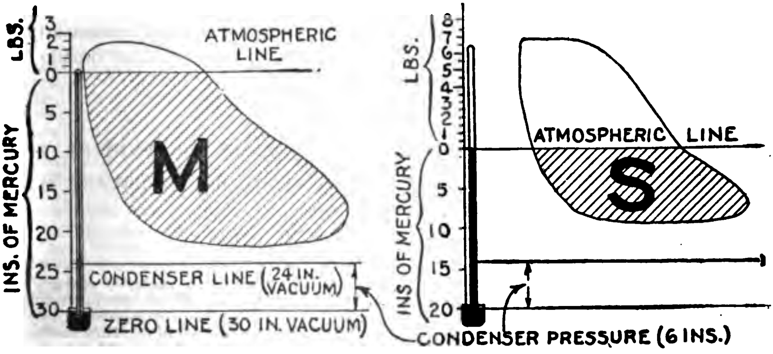


FIG. 5,609 and 5,610.—Indicator cards illustrating effect of barometer changes on condensing engine operation. In fig. 5,609, with 30 inch barometer a large proportion of the work is done below atmospheric pressure as indicated by the shaded portion M, of the card. Now if the barometer were to fall to say 20 ins. as in fig. 5,610, considerably less work would be done below atmospheric pressure, as indicated by the area S, which is much smaller than M.

or exhausting into a cold chamber, the steam will condense leaving a vacuum into which the piston can return without having to force back the atmosphere.

Thus, in fig. 5,612, steam is admitted during the up stroke, and in fig. 5,613, at the end of the stroke, the steam is shut off and a spray of cold water injected which causes the steam to condense and occupy over 1,600 times less space, thus forming a vacuum. This is the way the historical Newcomen engine ran. It was called an atmospheric engine because the steam pressure carried was but little above that of the atmosphere.

Instead of condensing the steam in the cylinder, Watt improved matters by introducing a separate condenser. With this arrangement the walls of the cylinder were not unnecessarily cooled by the injection water, and accordingly there was less loss by premature condensation, that is, condensation during the up stroke.

It must be evident that since, by condensation, most

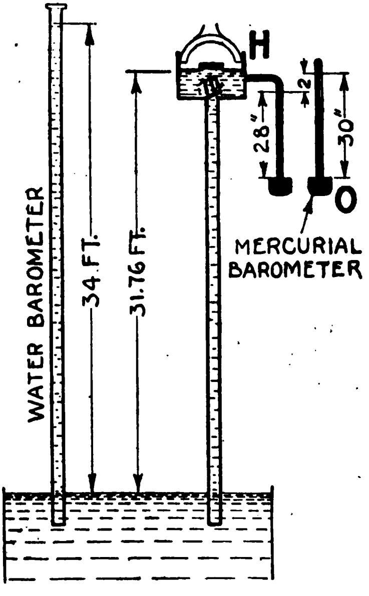
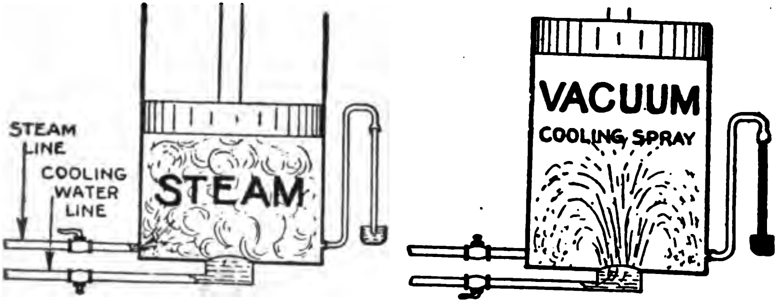


FIG. 5,611.—Operation of ordinary lift pump vacuum as measured by ***inches of mercury*** and ***feet of water***. ***As shown,*** the mercury in the barometer O, is at 30 ins. corresponding to atmospheric pressure of 14.74 lbs. Now for each lb. per sq. in. the corresponding head of water is 2.30947 ft., hence if water were used in the barometer instead of mercury the height of the column of water corresponding to atmospheric pressure of 14.74 lbs. (30 ins. of mercury) is 14.74×2.30947 = 34.042 ft., say 34 ft. The pump piston is 31.76 ft. above the water level, at which elevation a mercurial gauge attached at H, would read 28 ins. leaving only two ins. margin of available pressure to overcome friction and to lift the foot valve *m*. This distance 31.76 ft. is about as high as would be possible to lift the water with the barometer at 30 ins., and in practice about 25 ft. is considered the maximum lift for satisfactory operation.

of the back pressure is removed from the exhaust side of the piston, a considerable gain in power or saving is the result. The extent of this saving depends largely upon conditions of operation, the net economic effect being equal to the saving in fuel less the cost of condensing.

To obtain an idea of the nature and extent of the saving due to condensing, consider first the theoretical results obtained with



Figs. 5,612 and 5,613.—Newcomen's atmospheric engine illustrating effect of condenser in reducing the back pressure due to the atmosphere.

NOTE.—"The function of the condenser is to so cool down the exhaust steam as to reduce back pressure to a minimum, and in doing so the steam is converted into water. The very early engines could only work by the aid of condensation, as the steam with which they were supplied was generally of a lower pressure than the atmosphere, it is, in fact, owing to this that the steam engine owes its birth, for steam was preferred by the early mechanicians because it was so readily changed from gas to a liquid and so produced that vacuum which Nature was supposed to abhor, and to fill which she would do the work of horses. The exact relation of the condenser is better understood by following the early history of the steam engine from the day when the cooling water was admitted to the cylinder after the steam, and then allowed to run freely away from the bottom on the descent of the piston, to the time when Watt, having perceived the waste of energy in always forcing the piston up against the atmospheric pressure, and in admitting the hot steam into the cold cylinder, made the engine double acting, and effected the condensation in a separate chamber. The jet of water continued long after Watt's time as the means of cooling the steam, and gave in later days the distinguishing name to the condenser, which is now nearly entirely superseded by a more perfect apparatus."—*Seaton.*

NOTE.—A condenser may fail to work from a failure of the injection or circulating water supply, in which case the steam will not be condensed, but will accumulate in the condenser destroying the vacuum and heating up the condenser. Relief valves which open automatically to the atmosphere when the pressure in the condenser exceeds that outside are usually provided to allow the engine to keep on running non-condensing until the trouble can be located and remedied Again a condenser may fail to work on account of failure of the air pump to remove the water and air as fast as it comes to the condenser. Such a failure is apt to result seriously, for if there should be a vacuum in the cylinder at such a time, as there is likely to be by expansion in the low pressure cylinder of a compound or triple expansion engine, or even in a single cylinder engine when starting or stopping, or when lightly loaded the water will draw into it and result in a break down. For this reason condensers are often, and should always be provided with a device for automatically admitting air and breaking the vacuum when the height of water in the condensing chamber exceeds a safe limit, and care must be taken that nothing occurs to slow down the air pump if indirectly connected or independent.

1. Throttling engine. 2. Automatic cut off engine.

In the first instance, assume a throttling engine running non-condensing with 80 lbs. initial gauge pressure, and ½ cut off, as indicated by the theoretical diagram, fig. 5,614. The corresponding mean effective pressure is

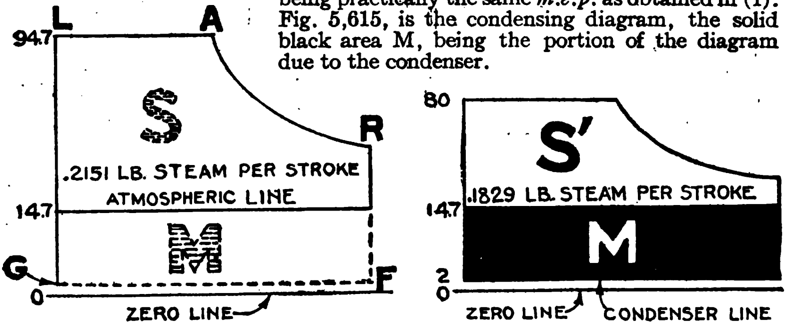
$$\frac{94.7\times1.69}{2} - 14.7 = 65.3 \text{ lbs} \ldots\ldots\ldots\ldots (1)$$

Now, if the engine be operated condensing, the condenser will reduce the back pressure to say 2 lbs., thus removing 14.7—2=12.7 lbs. pressure from the exhaust side of the piston.

Now since the cut off remains the same, for equal power, the throttling governor will reduce the initial pressure to approximately 80 lbs. absolute, giving a *m.e.p.* of

$$\frac{80\times1.69}{2} - 2 = 65.6 \text{ lbs} \ldots\ldots\ldots\ldots (2)$$

being practically the same *m.e.p.* as obtained in (1). Fig. 5,615, is the condensing diagram, the solid black area M, being the portion of the diagram due to the condenser.



FIGS. 5,614 and 5,615.—Theoretical diagrams for equal power of *throttling* engine operating non-condensing (sometimes ill-advisedly called "high pressure" operation), as in fig. 5,614, and condensing as in fig. 5,615. It should be distinctly understood that these are theoretical cards for engines without clearance being shown for simplicity and in practice the actual saving by condensing depends on many conditions. The solid black area M, is due to the condenser; hence, it must be evident that in governing by throttling when changing from non-condensing to condensing operation, the initial pressure is lowered until the card area S′ & M (fig. 5,615) is equal to S (fig. 5,614) thus maintaining constant load. Also if the initial pressure remained the same and condenser be added the card area S, would be increased by the area M, giving the cord L,A,R,F,G (fig. 5,614) increasing the power by area M. This is one way of increasing the power of an engine.

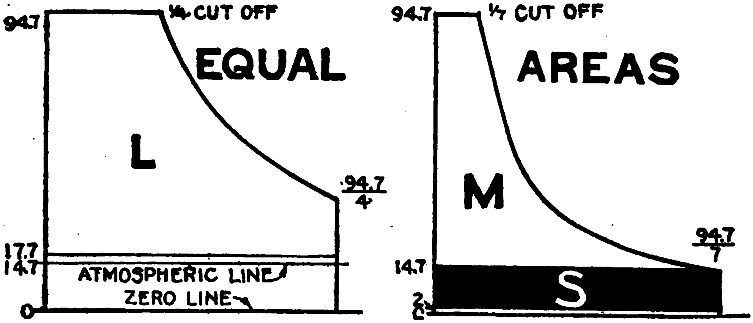
Again, if the volume of the cylinder up to the point of cut off be one cu. ft. (no clearance), it would require when running non-condensing one cu. ft. of steam at 94.7 lbs. which weighs .2151 lb., and when running condensing, one cu. ft. of steam at 80 lbs. pressure which weighs .1829 lb. Hence, when running condensing there would be an ***apparent saving*** of .2151 — .1829 = .0322 lb. per stroke, or

$$\frac{.2151 - .1829}{.2151} \times 100 = 14.97\%$$

Consider now the automatic cut off engine, running non-condensing, with 80 lbs. initial gauge pressure, and ¼ cut off, 17.7 lbs. abs. back pressure as indicated by the theoretical diagram in fig. 5,616, giving a mean effective pressure of*

$$\frac{94.7\times 2.39}{4}-17.7=38.9\text{ lbs}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Now if the engine be run condensing, the condenser reducing the back pressure to say 2 lbs., this will remove 17.7—2=15.7 lbs. pressure from the exhaust side of the piston, hence the engine governor would automatically shorten the cut off to some point such that the portion of the card produced above the atmospheric pressure line would give a mean effective pressure of 38.9—17.7=21.2 lbs. or the same *m.e.p.* of 38.9 lbs. for the entire card, thus giving constant power.



Figs. 5,616 and 5,617.—Theoretical diagrams for equal power of *automatic cut off* engine operating non-condensing, as in fig. 5,616, and condensing, as in fig. 5,617. Here the *area* of the card remains the same, but its contour changes. The solid black portion S, is the portion due to condensing, hence to keep the power constant the portion M, above the atmospheric line is reduced by shortening the cut off till M+S=L. The cut offs here shown are: ¼ non-condensing, and $^1/_7$ condensing are usually the most economical cut offs.

By trial and error the shortened cut off is found to be 1/7th, thus:

$$\frac{94.7\times 2.95}{7}-2=38.9\text{ lbs. } m.e.p.\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The diagram corresponding being shown in fig. 5,617.

Now, $\frac{1}{7}=\frac{1}{7}\div\frac{1}{4}=57\%$ of ¼, hence, the volume of steam to be admitted for $\frac{1}{7}$ cut off is only 57% of that required for ¼ cut off, and accordingly the ***apparent saving*** is

$$\frac{1-.57}{1}\times 100=43\%$$

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*NOTE.—In equations (1) and (2) above 94.7, is *absolute* initial pressure; 2.39 and 2.95 is 1+*hyp. log* of 4 and 7 (expansions) respectively.

In these two cases the saving is the *apparent* saving for as must be evident, if a feed water heater be used, the feed water could be returned to the boiler at a higher temperature when operating non-condensing than with a condenser, because some of the heat is carried off in the circulating water of the condenser, which otherwise would be absorbed by the feed water.

Thus the temperature of the exhaust steam at atmospheric pressure is 212° Fahr., and at 2 lbs. absolute, 126°, and assuming that with a feed water heater the water could be heated to these temperatures, its temperature would be 212—126=86° higher non-condensing than condensing. Now since there is a saving of approximately 1 % for each 10° that the feed water is heated, the saving in this case would be 8.6 %, which must be deducted from the apparent saving, and also the work of the condenser pump to obtain the net (theoretical) saving. The work of the condenser pump consists in pumping the water used in condensing the steam and removing air from the condenser.

Assuming 2° for this work, the net theoretical saving would be as follows:

		Throttling engine	Cut off engine
Apparent theoretical saving		13.48%	43%
Increased saving by feed water heating (non-condensing)............	8.6%		
Work of condenser pump..........	2 "		
	10.6 %	10.6%	10.6%
Net theoretical saving condensing...		2.88 %	32.4 %

Thus considerably more saving is obtained with the cut off engine than with the throttling engine, which is to be expected, because of the increased expansion of the steam.

Now in practice the net economy of condensing is somewhat less as explained in the note below.*

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*NOTE.—***Economy of Condensing.** "It is held in the popular mind that the economy of condensing is, in round numbers, 25%. This percentage usually relates to simple engines and it refers to the economy as measured by the difference in the coal consumption produced by a condenser." The evidence of some of Barrus' test shows that "this belief is not well founded except in special cases." "If the feed water be heated by the exhaust steam of the non-condensing engine to a temperature of 100°, which is that of the ordinary hot well, to a temperature of 210°, the non-condensing engine can be credited with about 11% less coal consumption, which should be considered in determining consenser economy." The average of a number of Barrus' tests gives a saving produced by condensing of 22.3%. "If we allow for the steam or power used by an economical condenser, it would be seen that the net economy of condensing is at best, not much over 20%, based on steam consumption. If furthermore, we allow for the difference produced by heating the feed water to the extent above mentioned, the ***saving of fuel*** would be reduced to about 10%."—*Barrus.*

Classification of Condensers.—Because of varied service conditions, there are numerous types of condenser, and these may be classed

1. With respect to the method of transferring the heat from the steam to the cooling water, as

a. Direct contact (jet condensers)........................... ***Class 1***
b. Surface contact (surface condensers)........................ ***Class 2***

Note these are the two general classes into which all condensers are divided.

2. With respect to the method of circulating the cooling water in *Class 1*, as

a. Rain.
b. Jet.
c. Barometric or siphon.
d. Exhaust steam ejector.

3. With respect to the method of circulating the cooling water in *Class 2*, as

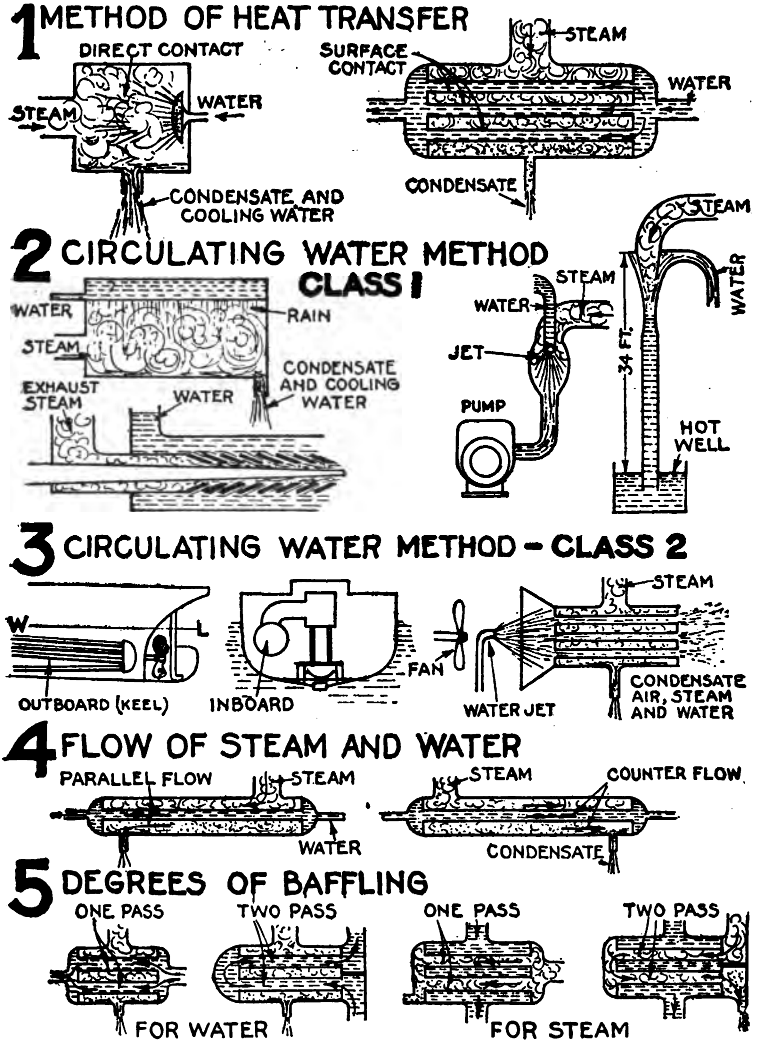
a. Keel.
b. Inboard (commonly called "surface").
c. Atmospheric.

4. With respect to the flow of the water and steam, as

a. Parallel flow.
b. Counter flow.

5. With respect to the degree of travel of the steam or water (extent of baffling), as

a. One pass.
b. Two pass, etc.



FIGS. 5,618 to 5,632.—Elementary condensers illustrating the classification given on page 3,109.

CLASS 1: JET CONDENSERS

A jet condenser is *a closed vessel into which a spray of cold water is "injected,"* hence the name "injection" water is usually given to the cooling water. Fig. 5,633 shows the simplest form of jet condenser. The steam from the engine cylinder passes into the condenser where it is almost instantly condensed by contact with a shower of cooling water, or so called injection water.

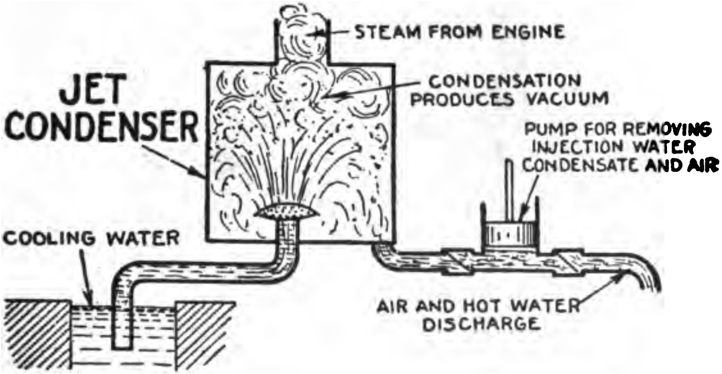

STEAM FROM ENGINE
JET CONDENSER
CONDENSATION PRODUCES VACUUM
PUMP FOR REMOVING INJECTION WATER CONDENSATE AND AIR
COOLING WATER
AIR AND HOT WATER DISCHARGE

Fig. 5,633.—Elementary jet condenser showing essential parts. The pump at the right is a so called air pump and erroneously called "vacuum pump" under the supposition that the pump produces the vacuum. It is, strictly speaking, a combined injection water, condensate and air pump.

Since each cubic foot of exhaust steam shrinks to about one cubic inch of water when condensed, an empty space or vacuum is thus created in the condenser. This vacuum draws in the cooling water which after contact with the steam is removed by a so called air pump.

There is always a small amount of air carried into the condenser, both with the steam and with the injection water, and also a large amount admitted through leaks.

In this type of condenser a single pump usually removes both the air and the water, although in the large sizes a so called "dry" air pump is used to remove the air only, as distinguished from a "wet" air pump which removes both air and water.

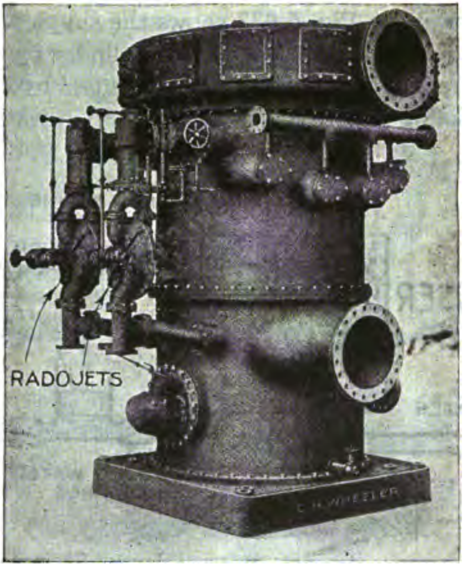


Fig. 5,634.—Wheeler low level jet condenser with "Radojet" air pumps to serve a 7,500 *kw.* turbine. The unit driving the circulating water removal pumps is not shown and may be either a turbine reciprocating engine or motor.

It is popularly supposed that the air pump creates the vacuum, but this is not correct and probably accounts for the erroneous name of "vacuum" pump for air pump. In reality it is *the condensation of the steam that produces the vacuum*, whereas the air pump *merely prevents the vacuum already created by the condensation of the steam being destroyed by the accumulation of air.**

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* NOTE.—If a dry air pump be shut down, a tight (surface) condenser will still operate for a considerable length of time with no change except a slight drop in vacuum.

Ques. What determines the degree of vacuum in the condenser?

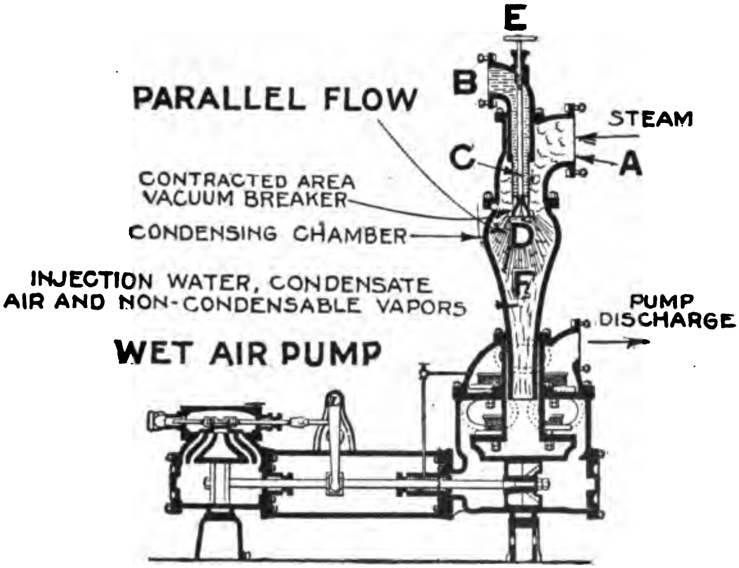

FIG. 5,635.—Parallel flow "jet" condenser. The condenser ***consists of*** a conical or bottle shaped casting projecting down into the water end of the air pump, and having openings in its upper parts for steam and cooling water. Since the cooling water comes into contact with the steam it will produce a higher vacuum with a given flow of cooling water than will a surface condenser, and the bulk and weight of the condenser itself is also less. When the condensed steam is to be pumped back into the boilers, the injection water goes with it, so that in this case the water supply must be of a quality which is not injurious to the boiler plates. ***In operation,*** the exhaust from the engine enters the condensing chamber at A, and the injection water at B. C, is the spray pipe which has at its lower extremity a number of vertical slits through which the water passes and becomes spread into thin sheets. The spray cone D, breaks the water passing over it into a fine spray and thus causes a rapid and thorough mixture of the steam and water. The spray cone is adjusted to give the proper amount of water by means of a stem passing through the top of the condenser to wheel E. The injection water and condensed steam fall together through the opening F, into the pump and are discharged into a convenient waste pipe, or into a hot well when the discharge water is to be used for feeding the boilers. The condensing chamber is ordinarily made from one-third to one-half the volume of the engine cylinder with which it is to be used. The injection water may be raised from a tank or other supply by the vacuum action of the condenser, provided the elevation is not more than 20 ft. If more than this, some form of pump must be used. ***In starting,*** first start the pump to produce a partial vacuum in the condensing chamber. This causes the injection water to enter through the pipe attached at B. The main engine may now be started, and as the exhaust enters through A, it meets the spray of cool water and is rapidly condensed, thus maintaining a constant vacuum. The condensing chamber tapers to relatively small size at the lower end, thus causing a rapid flow of water into the pump so that the air will be discharged with it instead of accumulating in the condenser.

Ans. Theoretically the highest temperature of the water in the condenser.

Any pump which takes air from the condenser must necessarily remove water vapor with the air. The vacuum therefore is not increased by pumping out this vapor, because since the pressure of the latter depends on the temperature, vapor will form faster than it can be removed.

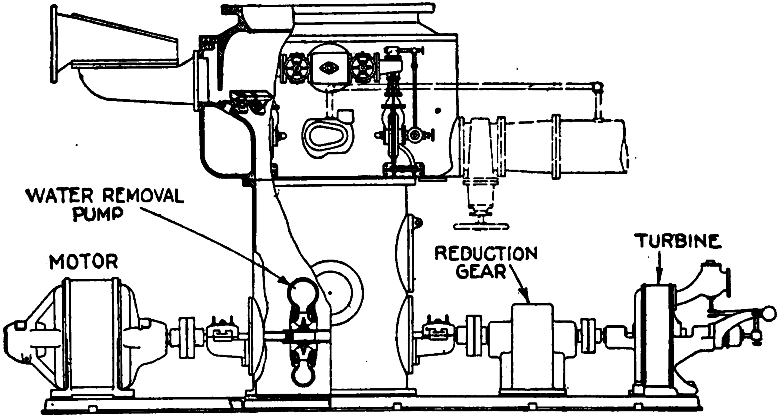

FIG. 5,636.—Wheeler low level jet condenser with radojet air pumps, multiplex atmospheric relief valve, and special drive for the removal pumps consisting of both gear connected turbine and direct connected motor providing for *heat balance* operation. *In operation,* water enters a distribution belt and flows at high velocity through nozzles, and is broken into a finely divided spray, which is carried downward by the velocity of the entering exhaust steam to the condenser base. The resulting intimate mixture is said to cause a hot well temperature not much lower than that of the entering exhaust steam. The air introduced into the condenser with the injection water, and by leaks together with the vapors that are non-condensable at the existing temperature are both drawn from the main mixture into an annular space directly above the injection water distributing ring, where they are cooled to as low a temperature as possible before being handled by the air pumps. Automatic vacuum heaters are provided to protect main engine or turbine in case of flooding.

Low Level or "Jet" Condensers.—The term *jet,* although it is applied too broadly to all condensers in which the steam and cooling water come into direct contact, is generally used to designate a low level condenser in which a pump is required to remove the water as distinguished from a high level or barometric condenser, which, as later explained, requires no pump. There are three general types.

1. Parallel flow.
2. Counter-flow.
3. Combined counter and parallel flow.

Fig. 5,635 shows the parallel flow type in which *the steam and water flow in the same direction.*

The cooling or injection water is supplied at the top through an adjustable spray cone which breaks it into small particles and thoroughly mixes it with the inflowing steam, thus producing rapid condensation.

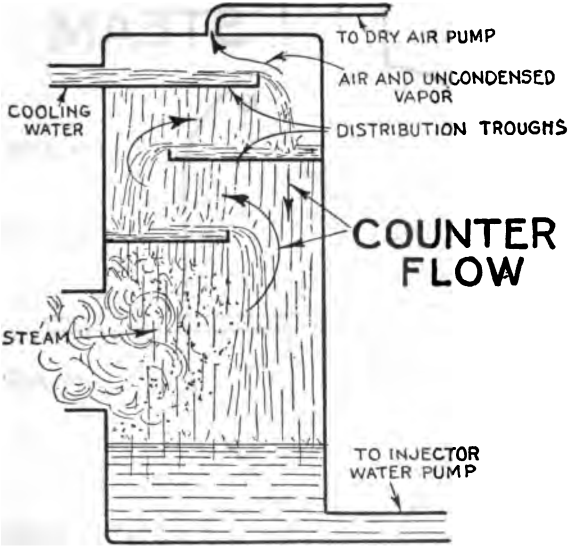

FIG. 5,637.—Counter-flow "jet" condenser. ***In this arrangement the steam and water flow in opposite directions***, that is, the entering steam encounters the warmest water and condenses as it rises, passing through successive curtains of water, obtained by suitably arranged overflow trays. Thus the temperature of the vapors is gradually reduced as they approach the top of the condenser, due to the proximity of the incoming injection water. Ultimately the mixture entering the suction pipe to the vacuum pump consists of air of relatively high density compared with that of the residual water vapors.

The mixture of condensate and cooling water is drawn from the bottom of the condensing chamber into the pump and delivered either to the sewer or hot well, depending upon whether the discharge water is to be used for feeding the boiler. If this be done the exhaust steam should pass through a grease extractor before reaching the condenser.

In designing a condenser of this type the volume of the condensing chamber is usually made from ⅓ to ½ that of the engine cylinder. The method of delivering the cooling water depends upon the lift. If it be not over 20 feet, it may be drawn up by suction, but if greater, a pump should be used. For high lifts of cooling water (15 to 20 feet), a priming valve and overhead water supply will be found desirable in starting the condenser; this supply should be shut off as soon as a vacuum is obtained.

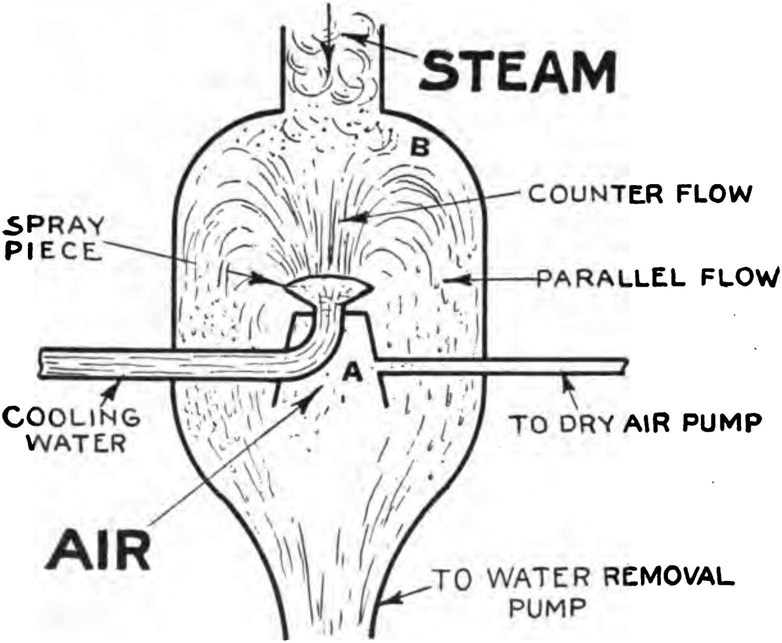

FIG. 5,638.—Combined counter-flow and parallel flow "jet" condenser.

Fig. 5,637 shows the counter flow type of jet condenser, ***in which the steam and water flow in opposite directions.***

With this arrangement, as is readily seen, ***the coldest water comes in contact with the coldest steam***, that is, with steam in its last stage of condensation, thus tending more to complete condensation in the condensing chamber and requiring a smaller amount of cooling water. In this arrangement the cooling water and condensate fall to the bottom of the condenser and are carried off by the injection water pump, but the air rises to the top of the condenser, being cooled as it rises, and is efficiently expelled from the top by a so called dry air pump.

Fig. 5,638 shows what might be called *a combined counter and parallel flow jet condenser*.

The air may be carried off either by a dry or wet air pump. The cut shows the dry air pump type. The air is drawn away at **A**, a point below that where the condensation takes place.

Any attempt at making a dry air pump connection at **B**, is useless, as the entering steam would prevent the collection of air and the net result would be the removal of steam only, which would not increase the vacuum.

Automatic Vacuum Breakers.—To protect the main engine or turbine from flooding, every jet condenser which depends upon a pump for the removal of the water is, or should be, provided with an automatic vacuum breaker, in case the water removal pump should fail. At the usual rate of flow a jet condenser would be entirely filled with water in a few seconds should the removal pump stop, unless provision be made to break the vacuum and thereby stop the suction of the incoming water.

There are numerous types of vacuum breaker depending for their action on the principle of

1. Reduced contact surface.
2. Air admission.
    - *a*. To condenser.
    - *b*. To cooling water pipe.

The reduced contact surface type consists simply of a constructed neck at the upper part of the condensing chamber as shown in fig. 5,639, which with undue rise of the cooling water causes the condensing surface to rapidly diminish it so that it is inadequate to condense the steam, thus causing the pressure to rise within the condenser.

The air admission types consist usually of a ball float, placed

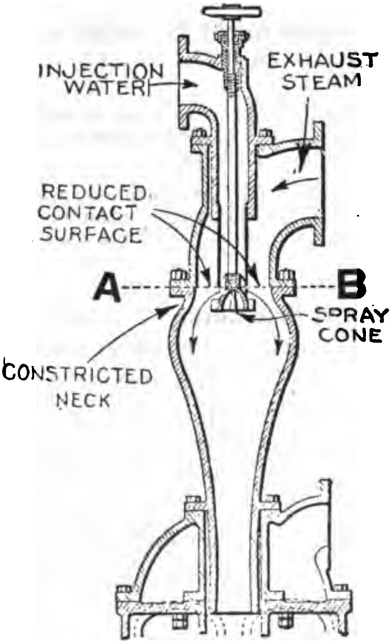

FIG. 5,639.—Low level parallel flow jet condenser showing Worthington ***reduced contact surface*** vacuum breaker. ***In construction*** the neck or upper part of the condenser chamber is made quite small and the cross sectional passage area is further constricted at this point by the cooling water pipe. ***In operation,*** rapid condensation is due only to the large surface exposed by the cooling water as it passes through the large section of the condensing chamber. Due to the constricted neck, any accumulation of water ***rapidly diminishes the condensing surface*** until the spray cone itself is submerged, leaving only the small annular ring of water at AB, to act on the large volume of entering steam. The surface of this ring being far too small to condense the steam, the pressure immediately rises causing the relief valve between the engine and condenser to open and allow engine to run non-condensing, or in the absence of a relief valve the exhaust steam will blow out through the cooling water pipe and pump valves, thus forcing all the water out of the condenser.

either in the condenser proper, or in an adjoining and communicating chamber, and which upon flooding of the condenser, will operate a valve and allow air to enter the condenser chamber or cooling water pipe.*

Fig. 5,640 shows an air admission vacuum breaker.

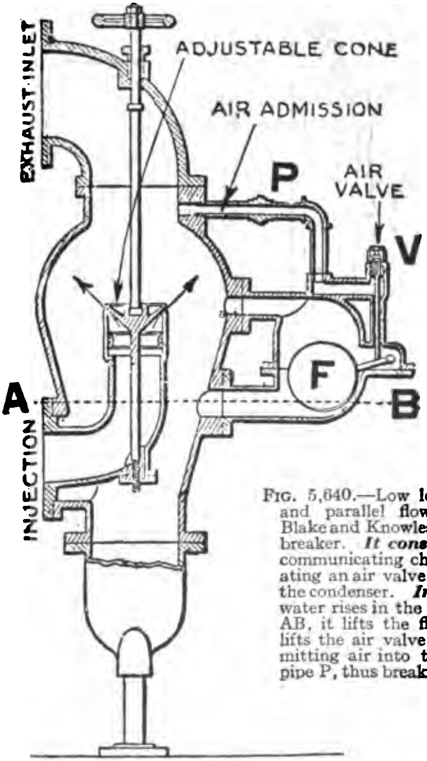

FIG. 5,640.—Low level combined counter and parallel flow condenser showing Blake and Knowles *air admission* vacuum breaker. *It consists of* a separate and communicating chamber with float operating an air valve which admits air into the condenser. *In operation,* when the water rises in the condenser to the level AB, it lifts the float F, which in turn lifts the air valve V, from its seat, admitting air into the condenser through pipe P, thus breaking the vacuum.

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* NOTE.—A vacuum breaker should not be confused with an atmospheric relief valve which is placed in the exhaust line between the engine or turbine and the condenser to provide a means of escape for the steam in case the condenser become disabled.

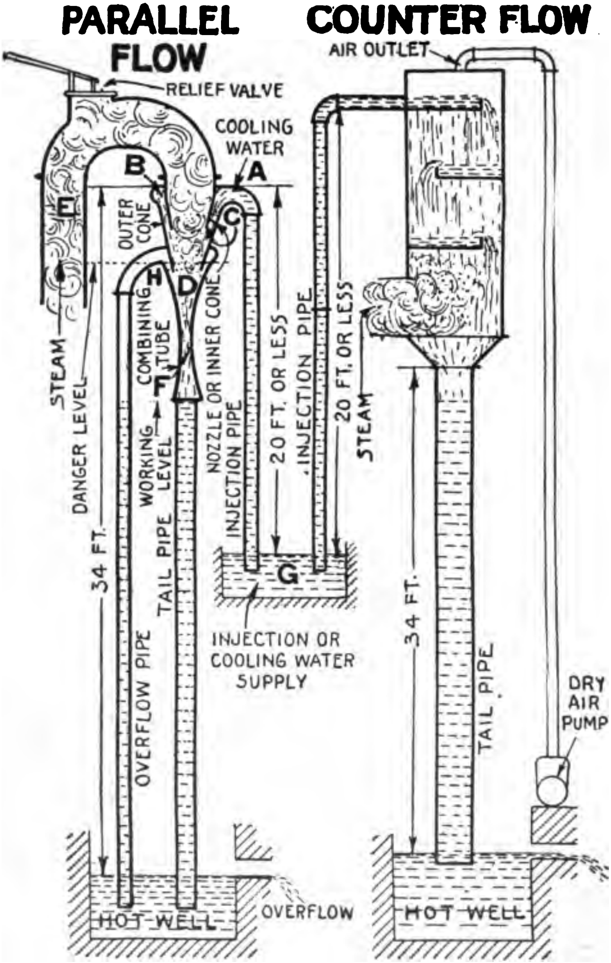

FIG. 5,641.—High level or barometric condenser; *parallel flow* or so called injector type. *It*

FIG. 5,642.—High level or barometric condenser; *counter flow* or dry air pump type. The

High Level or Barometric Condensers.—An economical and safe way to remove the hot water which results from the condensing process is to draw it off by gravity. To do this the condensing vessel is elevated to such a height that the column formed by the discharge water is sufficient to overcome atmospheric pressure, thus forming virtually a water barometer, with a height of 34 feet—hence the name "*barometric*" condenser.

FIG. 5,641.—*Text continued.*

consists of a steam discharge nozzle, combining tube and tail pipe terminating in a hot well. Two annular passages provide openings for the cooling water and exit to relief pipe. ***In operation,*** the cooling water enters the condenser at A, and circulates around the annular passage B, falling through the annular space C, between the outer and inner cones, forming a moving cone of water D, with a sharp vortex. Steam enters at E, passing through the inner cone or nozzle and meets the water at C, imparting to it what velocity it has on being condensed. This tends to force more water through the annular space between the inner and outer cones. The condensed steam, water, air and non-condensable vapors are brought down through the hollow cone of falling water D, and the air and non-condensable vapors discharged through the contracted throat F, of the combining tube. Since there is parallel flow of the steam and water, air and non-condensable vapors, the latter are forced by their own inertia to enter the vortex which effectively removes them. After passing the throat F, the combining tube expands to the size of the tail pipe, thus reducing the frictional resistance of the pipe to a minimum. For proper siphoning of the injection water the lift of the supply G, should not be over 20 feet. Now if the supply G, were very near the exhaust A, the pressure tending to force the water into the condenser would be considerably increased. Accordingly if this condition obtain, or if a pump be used and not properly regulated the water would enter A, faster than it could pass through the contracted throat F, and without the overflow pipe the water would fill up the condenser and probably back up in the exhaust pipe and damage the engine. Hence under such conditions, an overflow pipe as shown should be provided for safety. A relief valve I, is provided, permitting exhaust into the atmosphere when desired.

FIG. 5,642.—*Text continued.*

counter flow principal is explained in fig. 5,637. As shown the cooling water passes out to the hot well through the tail pipe, the steam inlet being 34 feet above the water level in the hot well. Air and non-condensable vapors pass out at the top as shown, to the dry air pump which may be placed in any convenient location. Since there is no contracted throat in the condenser an overflow pipe is not necessary as the tail pipe is large enough to carry off any excess cooling water which might enter the condenser.

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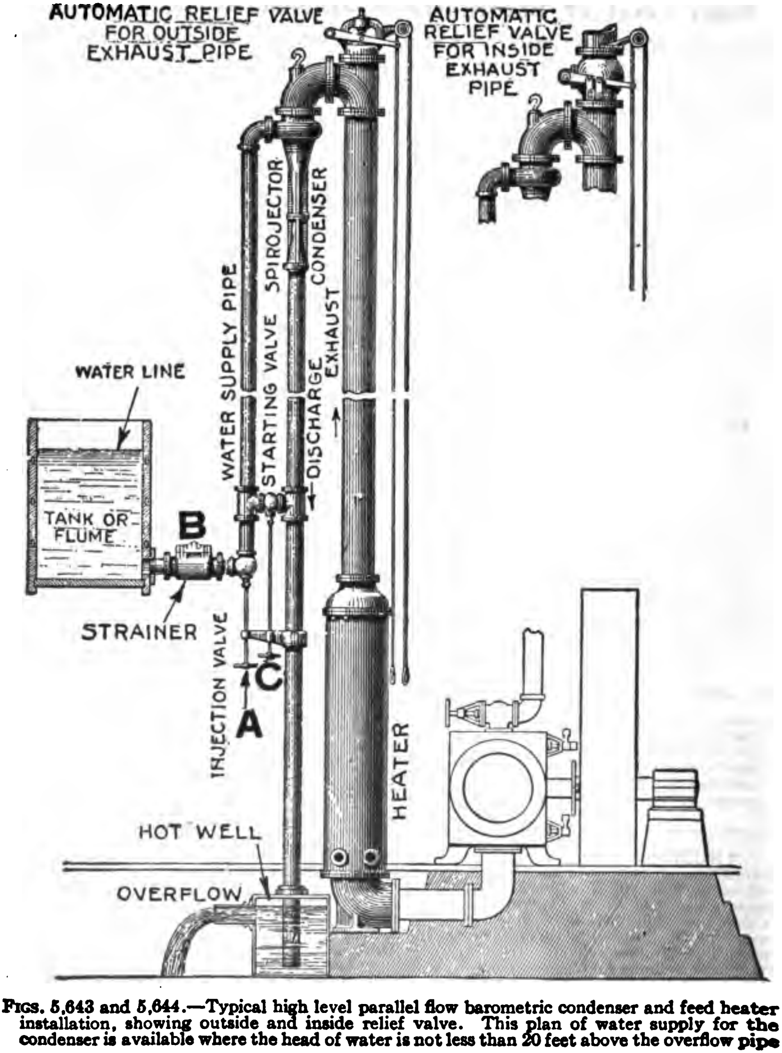
* NOTE.—If a sealed tube, say 36 feet long, be filled with water at the open end and then inverted so that the open end is immersed in a vessel of water, the pressure of the atmosphere will support the water in the tube approximately 34 feet above the water in the vessel and in the upper part of the tube there will be a vacuum. If more water were admitted into the tube at the upper end, it would have no effect on the water level in the tube hence if the exhaust from an engine be admitted to the tube at a point not less than 34 feet above the water level in the vessel (known as the *hot well*), it would be impossible for the vacuum to draw the water over into the engine cylinder and there would be no danger of accident from water reaching the cylinder ***unless, the cooling water entered the condenser faster than it could flow out without creating undue back pressure in the tail pipe,*** as in the case of pumping the injection water at too great speed. To guard against this some parallel flow barometric condensers are provided with an overflow pipe to take care of excess water, as shown in fig. 5,641.



Figs. 5,643 and 5,644.—Typical high level parallel flow barometric condenser and feed heater installation, showing outside and inside relief valve. This plan of water supply for the condenser is available where the head of water is not less than 20 feet above the overflow pipe

There are two general classes of barometric condenser:

1. Parallel flow or so called injector type.
2. Counter flow or dry air pump type, as shown in figs. 5,641 and 5,642 respectively, which illustrates the principles of operation as explained under the cuts.

Figs. 5,643 to 5,644 show barometric condensers as installed with valves and piping necessary for their proper control.

Jet Condenser Operation.—Where the air pump is directly connected to the engine, it starts and stops with the engine and its speed is the same or proportionate to that of the engine.

After the engine is warmed up as usual and ready to start, open slightly the auxiliary injection valve which admits water under pressure to condense the first few strokes of exhaust steam, since the air pump has not established a vacuum. Then open the throttle and gradually bring engine up to speed, at same time opening the main injection valve and closing the auxiliary injection after. The admission of water previous to starting protects the valves from the effects of the heat, although when the same are in good order sufficient water remains in the outfit to do so. When running under load the vacuum is regulated by the opening of the main injection valve.

Should it be necessary to run slow for any reason the main injection valve should be proportionately closed as the speed decreases to adjust the water admitted to the engine requirements and not let it flood the pump with the liability of its getting into the engine cylinder.

When stopping, gradually close the injection valve as the speed decreases, having same entirely shut by time the throttle is, to allow the last revolutions of the pump to remove the water. At this time some prefer to open

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FIGS. 5,643 and 5,644.—*Text continued.*

of the hot well. A supply pipe of sufficient size to prevent loss of pressure should be used to convey the injection water from flume, penstock or tank up to the condenser. On this pipe is placed, at the most convenient point, an injection valve A, for regulating the supply of water. A proper screen or strainer with a large number of small holes should be placed over the end of this pipe in the flume or tank, or a special box strainer of ample size as shown at B, should be placed on the pipe. The advantage of this form of strainer is the convenience with which it can be opened and cleaned. The cross pipe and valve shown at C, is for the purpose of starting the vacuum in the discharge pipe of condenser, and when sufficient vacuum is formed to cause the water to flow up the supply pipe and through the condenser, then this special valve C, is closed, and the amount of injection water is adjusted by the injection valve A. If the head of water should fall to about 10 feet above overflow of hot well, after the vacuum is once formed, the condenser will continue to syphon its water as long as the vacuum is kept up.

slightly the injection valve and for a few seconds to have valves covered with water.

Independently driven pumps are started in sufficient time to have the vacuum created by the time the engine is started and can be run at any predetermined speed irrespective of the engine.

As this pump has its own motive power it can create a vacuum of its own accord, thereby causing water to enter the condenser without the use of an auxiliary injection being resorted to. The condenser thus drains the engine cylinders and piping of water when warming up, etc.

The engine is started exhausting into condenser at the beginning. Some, however, prefer to have the main valve closed when starting and remain so till the engine has its load, the condenser pump running the while, then open said valve, allowing steam to enter the condenser. This method is the safest, as some systems of piping make it possible for the water to enter the cylinder whenever there exists a greater vacuum therein than in the condenser.

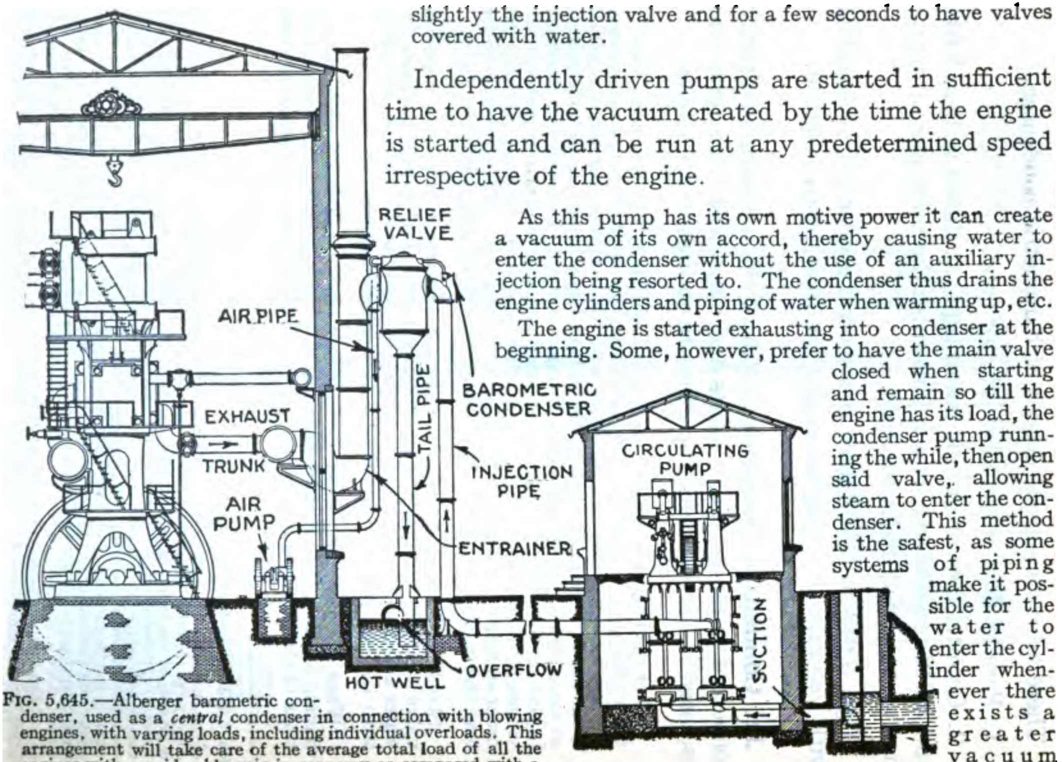


FIG. 5,645.—Alberger barometric condenser, used as a *central* condenser in connection with blowing engines, with varying loads, including individual overloads. This arrangement will take care of the average total load of all the engines with considerable gain in economy as compared with a plant having the same engines equipped with individual condenser and air pumps.

After the spray valve is once adjusted for best results it is seldom touched. All regulating being in connection with speed of pump and the injection valve. The handling of spray valve may be summed up as follows: When it is remembered it is usually the difference of pressure between the outside and inside of the condenser that causes the water to rise and enter same, it will be readily seen that the water has considerable pressure back of it, and if the slots in the spray head be partially open, part of the water spurts out to a greater distance than if the head were completely open and thus more nearly fills the condensing chamber, giving greater area for condensing the steam which is the condition desired.

If the valve be open too wide the water simply rolls over the edges of the spray plate, presenting less area, so that the vacuum drops and the condenser heats up, no matter how far the injection valve is opened. A wide open valve would flood the condenser, again reducing the condensing area and if the speed of the pump has not been changed, the increased weight of water to be handled will reduce its speed and cause a still greater loss of vacuum, finally opening the automatic valve. So with variable load it is customary to run the condensing apparatus for maximum load the greater part of the time to be ready for it when it comes.

If the vacuum decrease and the speed of the pump be about right, try adjusting the injection valve, then speed of pump and work the two together. In severe cases the spray valve might have to be moved.

When shutting down, close the throttle first, then the injection valve, then after the engine has stopped shut down the air pump, which has now had time to remove the water from the piping, condenser, etc.

Some stop by shutting down the condenser valve and letting the engine exhaust outboard. When using an independent pump it is proper to run it at such a speed that its action indicates slipping. Slipping means that the piston reverses so quickly at the end of its stroke that the valves in the water end do not seat before the direction of the piston is reversed, although the steam end is taking as great a volume of steam as when the speed is sufficiently slow to allow the water valves to seat prior to the reversing of the stroke. At first sight it might appear to be wholly a loss, but this is not the case, as it must be remembered that in all condensers there is always some vapor and air present and that the motion referred to is when the greater portion of such enters the pump cylinder. If it were allowed to accumulate by a lower pump speed, the vacuum would, of course, be less.

Exhaust Injector or Induction Condenser.—The operation of this condenser is based upon the same principle as that of the steam injector, that is, *the kinetic energy of a jet of steam escaping from a boiler is* **greater** *than that of a jet of water escaping under the same conditions.*

A jet of steam enters through the steam tube at a high velocity and induces the air in the suction pipe and injector body to pass out with it; this leaves a vacuum and allows the atmospheric pressure to force in water. The steam is condensed by this water and the velocity of the steam is imparted to the water; then the energy in the moving column of water is sufficient to overcome the pipe friction, lift the check valve and force the water into the boiler against the pressure.

The condenser shown in fig. 5,646, however, has its limits of operation. The operation, as just stated, depends upon the velocity of the discharge; it is plain that when the condenser lifts its injection water, as shown in the figure, this velocity must be almost wholly imparted by the exhaust steam. Then if the load on the engine be variable or if the condenser be too large for the engine, there will be times when the small amount of exhaust steam furnished by the engine will not be enough to impart the required velocity to the large volume of water and the condenser will not operate satisfactorily. In other words, the volume of exhaust steam must be, within limits, in proportion to the volume of water which it keeps in motion, too little steam being unable to induce the flow of water and too much steam affecting the vacuum. The minimum amount is that which will increase the temperature of the water at least 30° F. and the maximum amount is that which will not cause a rise of more than 50° F. in the water temperature.

In cases where the condenser takes its water under a head, as shown by dotted lines in fig. 5,646 this objection does not apply, for then the velocity of the water is that due to the head and is independent of the exhaust steam.

In order to guard against the trouble due to a varying amount of exhaust steam, the condenser shown in fig. 5,647 has been devised. It is called the adjustable capacity condenser in order to distinguish it from the fixed capacity condenser shown in fig. 5,646. Both the condensers shown were designed by Korting.

An inspection of fig. 5,646 shows that an atmospheric outlet must be provided for the exhaust, just as in the cases of the jet, surface and siphon condensers. The figure shows a special swing check valve for this purpose, while on the adjustable capacity condenser in fig. 5,647 is shown the automatic valve usually furnished with this type of condenser.

In this condenser there is no 34-foot tail column, and in case the low pressure cylinder of the engine acts as a pump, water may readily be drawn up into the engine.

This is prevented by the arrangement of the stop valve E, through which the exhaust steam enters the condenser. The valve itself is not fixed to the spindle, but is free to move vertically within the limits set by the seat at the bottom and the collar C, on the spindle at the top. It thus allows steam to pass out under it from the engine into the condenser, but acts as a check valve against the passage of water in the opposite direction or from the condenser to the engine. It may also be used as a stop valve by lowering the spindle until the collar C, locks the valve to its seat. Since the seat of this valve is practically at the top of the exhaust pipe, it is advisable to drip the pipe on the engine side of the valve, as shown in fig. 5,646, to prevent any accumulation of condensation. This drip may be piped into the condenser as shown, with a check valve arranged to prevent the return of water from the condenser to the exhaust pipe

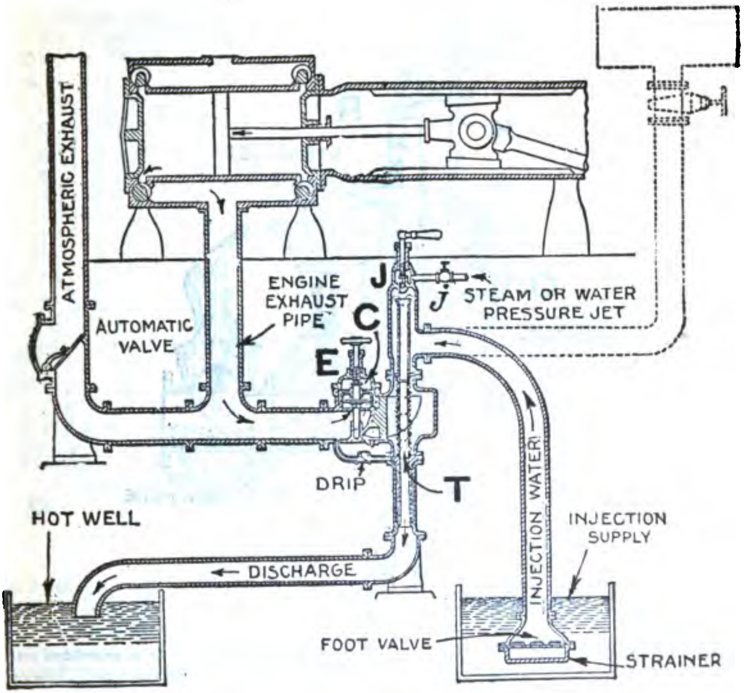


FIG. 5,646.—Erhart steam induction condenser. ***In operation,*** exhaust steam enters through the valve E, and passes through the inclined perforations into the central tube T, as shown by the arrows. Owing to the velocity of its movement the air in the condenser and the injection pipe is drawn out with it, and the atmospheric pressure on the injection supply forces the condensing water up through the pipe and into the tube T, as shown. The exhaust steam is condensed by this water and a vacuum is left in the condenser and exhaust pipe. The original velocity with which the water entered the condenser and the added velocity due to the exhaust steam enable the mingled steam and water to overcome the atmospheric pressure on the discharge end and pass out into the hot well, just as the water from the injector overcomes the resistance due to friction and pressure and passes into the boiler. Evidently then the velocity of the discharge is sufficient to draw out the air and to get rid of the condensing water and condensed steam; so that no air pump is required as in the case of a jet or surface condenser, nor a 34-foot "tail" column, as in the injector or siphon condenser. ***To start engine:*** When the condensing water is under a head, turn on the condensing water and when a vacuum is formed, start up the engine. When the condensing water must be lifted, open the steam or pressure jet valve *j*, and as soon as this has lifted the water start the engine. The operation of the condenser will begin as soon as the engine exhaust reaches the condenser and when the vacuum is formed the suction or lifting jet may be turned off. In shutting down, stop the engine first, when the operation of the condenser will cease if the condensing water is under a suction lift; if the water supply is under a head, stop the engine first and then shut the valve in the water supply pipe.

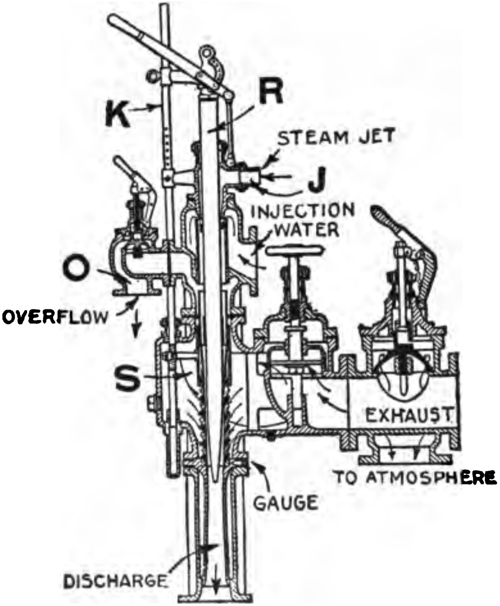
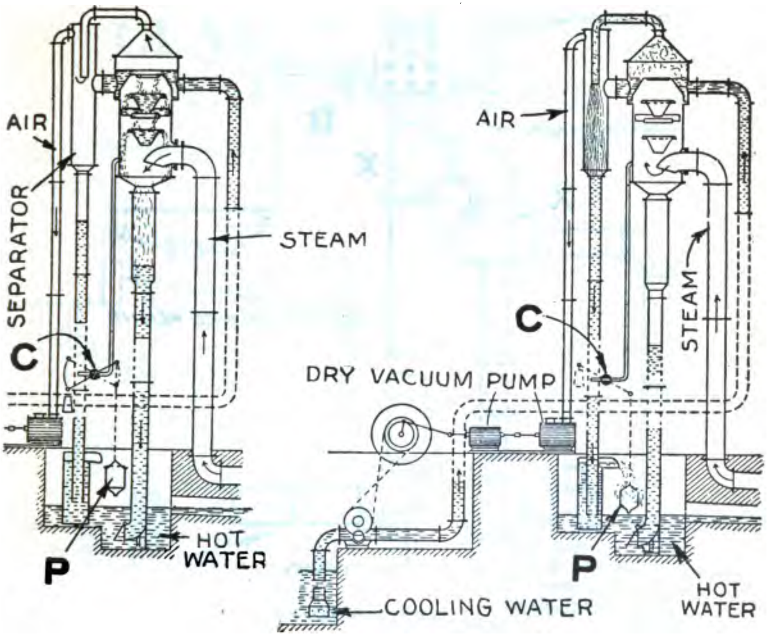


FIG. 5,647.—Koerting adjustable exhaust steam induction condenser. *It is provided with* a movable ram R, inside the central water tube and a sleeve S, outside the tube. The ram is tapering and controls the volume of water admitted by increasing or diminishing the annular space between its surface and the inside of the tube; while the sleeve S, by covering more or fewer openings in the tube, governs the area of the exhaust inlet and consequently the velocity of the exhaust steam. The relative positions of the ram and the sleeve can be regulated by the extension rod K, so that the machine can be adjusted for almost any condition of load. In fact, the machine may be adjusted to work satisfactorily at any point from ¼ or 1/5 of its capacity to full capacity; this is particularly desirable, when the load is variable and the injection water must be lifted. On the other hand, the range of the fixed capacity condenser is only from about one-half capacity to full capacity. For high suction lifts, the live steam jet or water pressure jet J, is used to bring the water to the condenser, and an escape is provided through the overflow valve O, just as in the case of the steam injector. This starting jet and overflow valve are necessary only when starting, and may both be omitted when the suction lift is very small or when water is supplied under a head. It will be seen that in this condenser, the condensed steam and the condensing water are mixed together, so that the water from the hot well can not be used for boiler feed unless the condensing water is pure.



Figs. 5,648 and 5,649.—Weiss high level or barometric counter flow condenser. Franz Joseph Weiss, of Basle, Switzerland, began in the early nineties to develop the possibilities of the barometric condenser for high vacuum. He called attention forcibly to the fact, that the absolute pressure existing in the condenser was the *sum* of the vapor pressure (that is, the pressure of steam as given by the steam tables for the temperature of the water content of the condenser) and of the air content. The absolute pressure could not get down to that due to the temperature, except in the absence of air, but the lowest pressure in the condenser would be at the coolest point, for here the vapor pressure would be smallest and to this point the air would tend to flow. His condenser was therefore made on the counter-flow principle, as shown in fig. 5,648. The injection water enters at the top, as shown, and trickles down over a series of shelves or bowls, while the dry air pump draws from the top. The point of least pressure will obviously be at the top, and to this point any air or vapor not condensed at the entry or carried down into the tube will make its way, encountering cooler and cooler water as it arises, until at last only the air or the absolutely non-condensable vapor reaches the air pump, and this at the temperature of the incoming coolest water. The air is drawn off through a separator which has a barometric tube to discharge the water which comes over with the air. With this arrangement it is possible to get the vacuum, or the absolute pressure, down to that due to the temperature, but as this "ideal point," as the inventor terms it, is reached, the water is apt to rise and pass out by the air pipe at the top, as shown in fig. 5,649. In other words, the condenser reverses itself and becomes a parallel flow instead of a counter flow apparatus, and having once established itself in this way it will continue to run so until the condenser is stopped and started over again right. In order to do this automatically, a pail P, is suspended so as to receive the flow from the barometric tube of the separator. This pail has an outlet in its bottom sufficiently large to discharge the normal flow as fast as it is received, but when the condenser reverses, and the water comes in large quantities the pail fills, overcomes the weight at the other end of the lever, and turns the cock C, connecting the chamber into which the incoming steam is discharged with the barometric leg of the

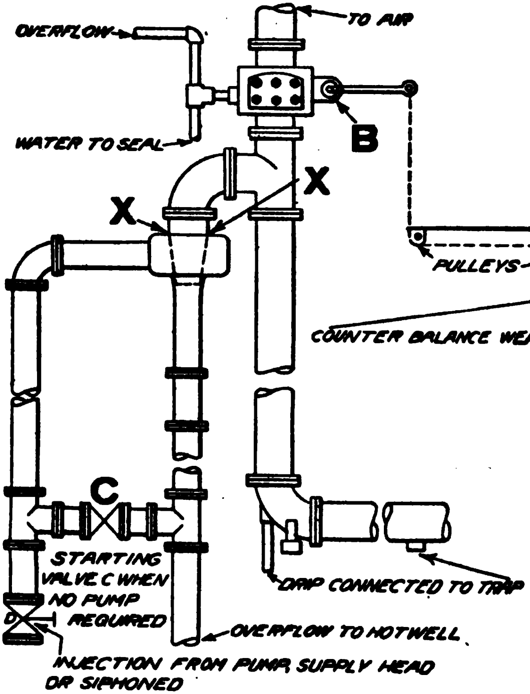


FIG. 5,650.—Typical high level or barometric condenser connection. ***In operation***, whether it be necessary to stop the engine to build up the vacuum depends upon conditions, but usually the vacuum may be built up with the engine running. If the condenser be not of proper size or have air leaks in the piping, if there be an irregular supply of injection water, or the load come on before the engine is up to speed, or with a long run of pipe between condenser and cylinders, it may be necessary to stop the engine. Then build up as high a vacuum as possible and start the engine. When the vacuum is lost with the engine carrying load, when all has been well up to this time, the trouble will usually be found due to some trifling cause which, when removed, allows the vacuum to build up to normal. Disregarding general pump troubles, poor vacuum or total loss of vacuum may be caused by any one of the following causes: The strainer may be clogged on the injection pipe, reducing the flow of water. The relief valve cap has a rubber packing ring which, due to the clapper being allowed to hammer on its seat, soon leaks and ought to be renewed. These valves ought to be water sealed. If they leak, and usually they do, the sealing water may be cut off so that they are

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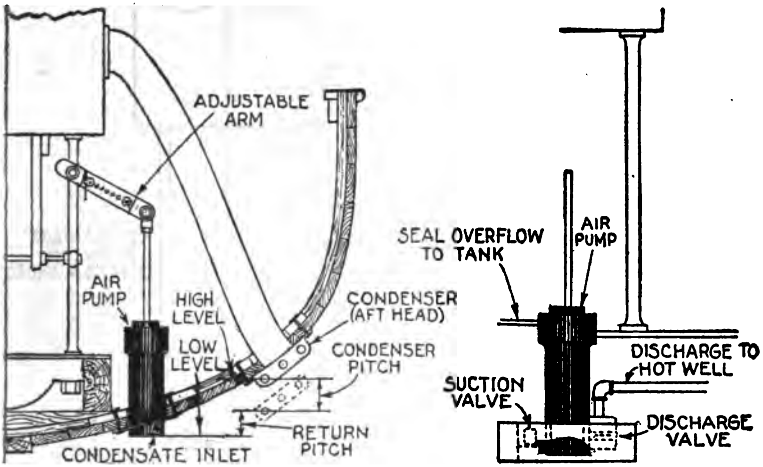
FIGS. 5,648 and 5,649.—*Text continued.*

separator, which equalizes the pressures and reverses the action, turning the condenser back into a counter-current C. Particular stress is put by Weiss upon the fact that the advantage of the counter-current condenser lies not in the reduction of the volume of the air to be pumped by securing the greatest possible reduction of temperature, although that is an advantage, but in the fact that by maintaining the point of lowest temperature at the intake of the dry air pump he establishes a definite and positive flow of air to that point, so that the pump draws air, not steam vapor, and all the air is taken out.

CLASS 2: SURFACE CONDENSERS

As distinguished from jet condensers, the surface condenser



Figs. 5,651 and 5,652.—Method of getting the air pump suction below a keel condenser in order that the condensate will drain into the pump; an important condition for obtaining high vacuum, and one usually overlooked in most installations (see page 1,651). The air pump instead of being attached to the bed plate, is located at considerably lower level by means of a special casting which projects through the hull, being secured by an outboard flange (forming part of the casting) which forms a tight joint as shown. With this arrangement the suction valve is at the lowest level of the return pipe thus securing the ideal working conditions. Proposed arrangement for steamer *Stornoway II*.

Fig. 5,650.—*Text continued.*

not sealed. Of course, the stuffing boxes on the engine and pump, when one is used, ought to have proper attention and be kept tight. The stuffing boxes on all water lines to the condenser should be included in this, also the vacuum breaking valve and its disc renewed when required. The trap and drain valves which discharge the condensation from the exhaust pipe should be frequently examined to see that they are clear and seat properly. Care must be taken to see that the stuffing box on the relief valve shaft at B, is not so tight as to make the valve sluggish or it will be difficult for it to seat itself. The counterbalance weight must not be too heavy or the valve will not close automatically when it opens. Care must be taken to see that the chain or cable used to connect the counterbalance weight to the relief valve is in the guide pulleys. When no pump is used to supply injection water, one can usually re-establish the vacuum by starting the engine in the regular manner, in the meantime exhausting out board. First open priming valve C, and after a few seconds open the main injection valve, lowering the relief valve on to its seat. In a few seconds the vacuum builds up to 18 in. or so, when starting valve C, is closed and vacuum regulated by injection valve D. A forced primer would be used in the same way. The pump, when necessary, could have been started and its speed governed according to the vacuum carried.

may be defined as *a device for condensing steam in which the steam and cooling water do not come into contact with each other, but are separated by metal surfaces.*

The surface condenser was first employed by James Watt, but was dismissed by him on account of the cumbrous nature of his apparatus, and its use was not revived until 1835.

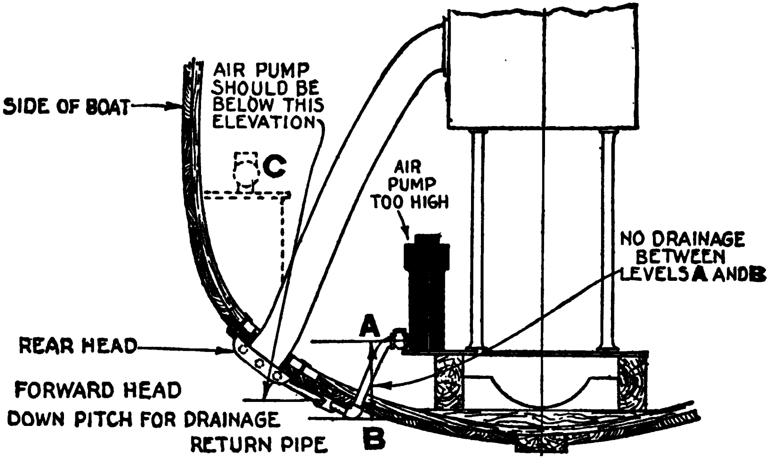
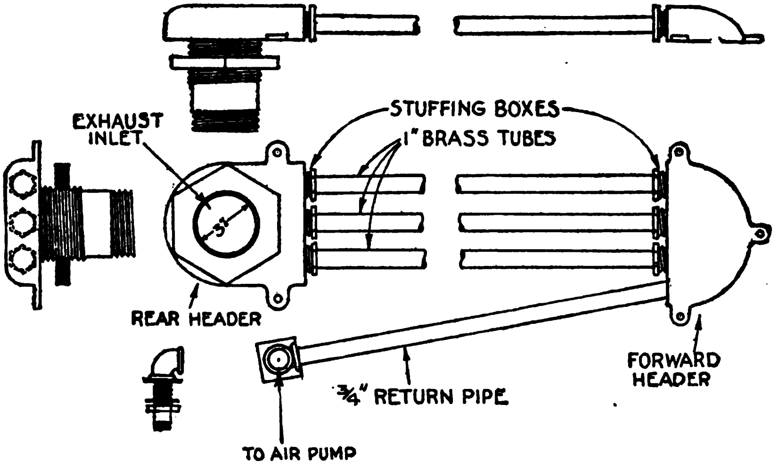


FIG. 5,653.—Section through steam launch *Stornoway I,* showing faulty installation of keel condenser. With the necessarily high elevation of the air pump the condenser will not drain, hence ***in operation,*** the attempt of the air pump to produce a vacuum in the condenser is opposed by the resistance due to a column of water whose height equals the dimension BA. ***For example,*** if the temperature of condensate be 100° Fahr., the maximum vacuum possible is 28 ins., and further if the column of water in suction pipe between levels B and A, be 1 ft., it will offer a resistance of .43 lb. per sq. in. which is equal to .87 in., thus reducing the vacuum from 28 to 28 − .87 = 27.13 ins. *in the condenser.* This vacuum is further reduced by 1, the inefficiency of the pump 2, friction of the condensate en route to pump, and 3, the non-draining feature which causes spasmodic flooding in the return pipe. Hence, ***in practice,*** if a 28 in. vacuum were aimed at under the above conditions, probably not more than 24 or 25 ins. would be obtained, and accordingly the importance of arranging the apparatus, as shown in fig. 5,651, so as to reduce these losses to a minimum. The importance of this is further emphasized by an experience of the author with an independent air pump C (shown in dotted lines) located at a high level, and connected to the condenser by a suction line having a multiplicity of elbows. With this faulty rig only about 15 or 16 ins. of vacuum could be obtained.

Outboard or Keel Condensers.—About the simplest form of surface condenser is the keel condenser, which is the usual type fitted to steam launches, as in small boats the inboard condenser would take up considerable room and add considerable extra weight beside requiring a pump to circulate the cooling water.

It consists of a brass or copper tube, or several tubes attached to the hull outside below the water line and running fore and aft near the keel (hence the name *keel* condenser).* The exhaust from the engine enters at one end, is condensed by the cold water, and drawn out of the other end by the air pump. This is a very simple arrangement, since no pump is needed to circulate the cooling water. The passing of the boat through the water takes the place of a pump for this purpose.



FIGS. 5,654 to 5,657.—Construction details of keel condenser of steam launch ***Stornoway I.*** The heads are provided with stuffing boxes for the tubes, and in addition the forward header has an additional outlet tapped with ¾ pipe tap for the return to air pump, the return being standard weight brass pipe. A special elbow with flange for fastening to hull, passes through the planking and is secured on the inside by a washer and nut. The return pipe is fastened to the elbow by long screw and lock nut joint.

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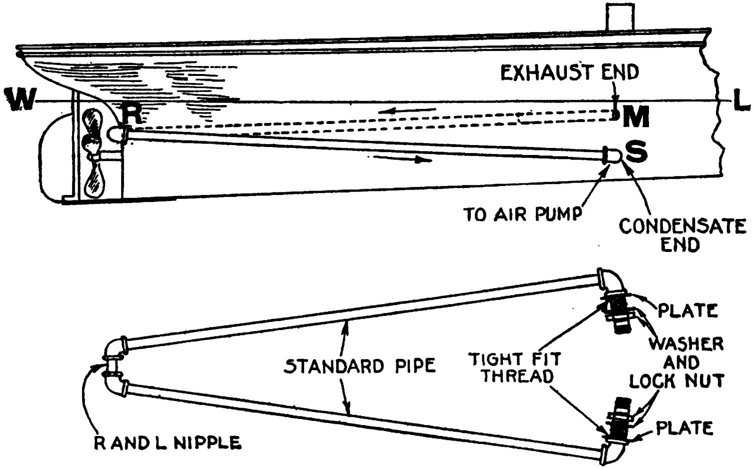
*NOTE.—A form of keel condenser known as *bastard condenser*, is sometimes fitted to canal boats and other non-descript vessels. *It consists of* the ordinary keel condenser with outlet open to atmosphere and high enough to drain into the hot well. Such makeshift apparatus *operating without vacuum* is inexcusable.

The important point about keel condensers is that *the tubes and return pipe must be inclined so that the condenser will draw toward the air pump; otherwise it would flood and fail to produce a good vacuum.*

This point has been explained and emphasized on page 3,132. The general construction of a keel condenser is shown in figs. 5,654 to 5,657. This is the best construction, though rather expensive. For an ordinary job a condenser can be made of ordinary standard weight pipe as shown in figs. 5,658 and 5,659.



FIGS. 5,658 and 5,659.—Ordinary keel condenser made of standard pipe and fittings. Fig. 5,658, assembly on boat; fig. 5,659, construction detail. The exhaust should be piped through the hull at M, very near the water line so that there will be as much pitch as possible between M, and S, as it should be remembered that thorough and quick drainage is very important in keel condensers.

Inboard Surface Condensers.—The name *inboard* is here applied to distinguish the ordinary form of surface condenser from the keel type. The modern surface condenser is formed of small brass tubes, usually ⅝ inch to ¾ inch diameter and 5 to 10 feet long. The common arrangement is to place the tubes horizontally in a cylindrical or rectangular box and to admit the water in at the bottom and the steam at the top. The best practice is to bring the water through the tubes and the steam outside, as shown in fig. 5,660. The heat is thus drawn from every direction, indicated by the arrows, and absorbed by the rapidly moving cooling water. This water is generally

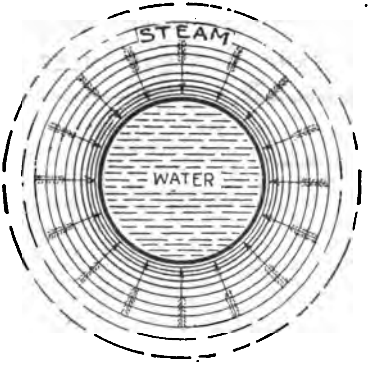


Fig. 5,660.—Section through condenser tube illustrating the action of condenser with cooling water passing through the tubes and steam outside. The almost universal practice is to circulate the water through the tubes as here shown.

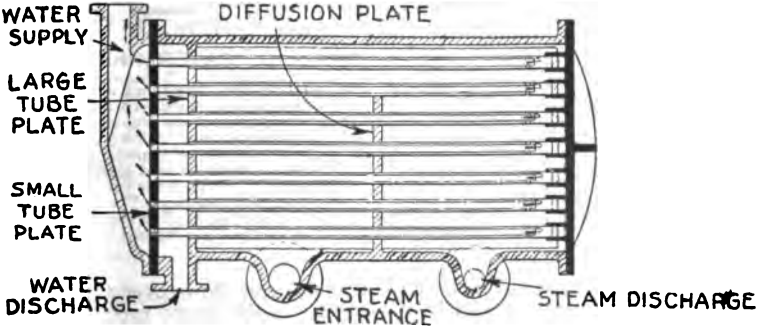


Fig. 5,661.—Miller double tube condenser (patented in 1869). ***In construction,*** small tubes are placed inside of large ones. The water first passes through the inner tubes and returns through the outer tubes, and after absorbing the heat from the steam, is discharged into air pump. This type was extensively used at one time, but at present the single tube represents the prevailing practice.

called the *circulating water*, and its circulation through the condenser is maintained by a pump called the *circulating pump.*

The water formed by the condensed steam and the accumulating air are drawn away by a similar pump called the air pump.

Whether the cooling water or the steam flows through the tubes is the distinguishing mark between the two general types into which surface condensers are divided.

In the one type, known as the standard surface condenser, the water flows through the tubes while the exhaust steam flows over the outside surface of the tubes and is there condensed. In the second type, known as the water works surface condenser, the water flows over the outside of the tubes while the steam flows through and is condensed within them. The latter type is a special type and is used for the special conditions usually found only in water works pumping stations.

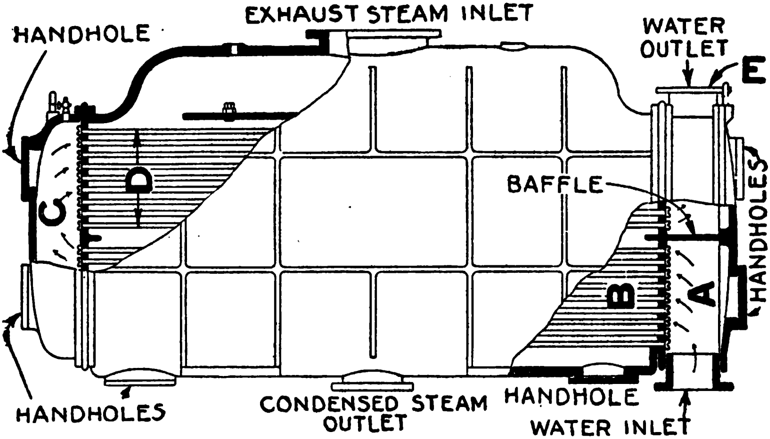


FIG. 5,662.—Single tube standard condenser. ***In construction,*** the tubes are commonly made ¾ inch outside diameter of solid drawn brass tinned on both sides. To allow unequal expansion of the shell and tubes screwed glands and stuffing boxes are provided; these are packed with cotton cord or corset lacing. The tube sheets or plates to which the ends of the tubes are attached are of brass and usually from 1.1 to 1⅛ times the diameter of the tube in thickness. The type of joint determines the thickness. With screwed glands a thinner plate may be used than when the packing extends through it. Usually the tubes are spaced in a zigzag manner, pitched from 1.5 to 1.7 of their diameter on centers. The tubes, plate, ferrules, nuts and washers should be of brass to prevent corrosion. The shell is generally made of cast iron; no wrought iron should be used when the parts are exposed to the distilled water.

The surface condenser permits the use of impure or salt cooling water without bringing same into contact with the condensate, hence the condensate is available for use as boiler feed. For this reason the only type of condenser that can be used for marine service on salt water where the condensate is to be used as feed water, is the surface condenser.

Figs. 5,662 and 5,663 show the general construction of single and double tube condensers. The condensing chamber is made of cast iron and usually supported above the pumps, where independent pumps are used as in fig. 5,663. Here the water or circulating pump is shown at the right and the air pump at the left. The air, water, and steam pistons are attached to a common rod, with the steam cylinder in the middle, as shown. Exhaust steam enters the chamber at **A**, where it strikes a baffle plate, which serves to distribute it over the cooling surface and also to prevent its cutting the

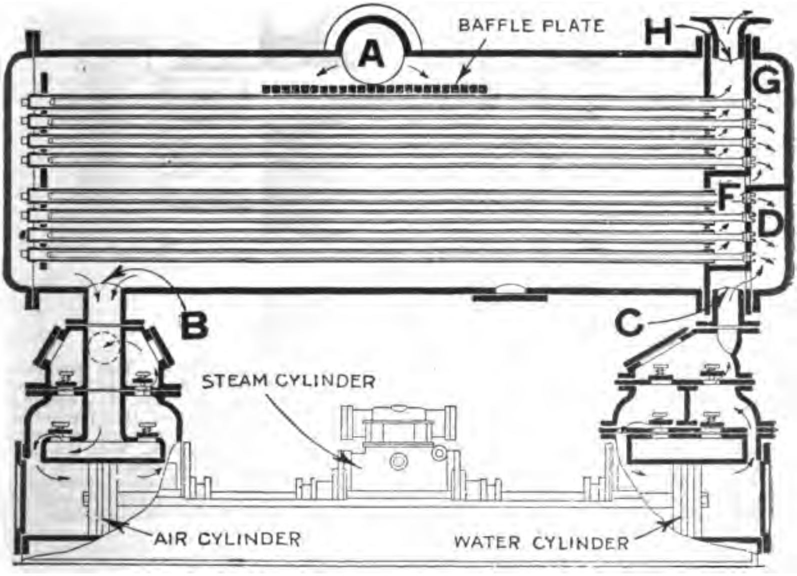
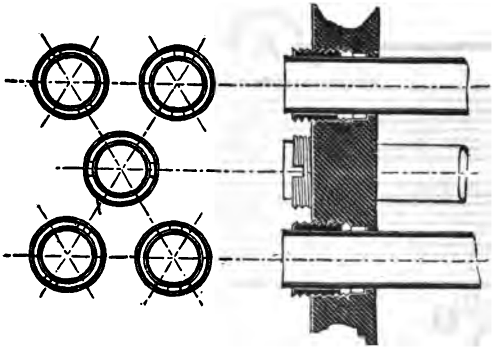


Fig. 5,663.—Double tube standard condenser. The tubes are secured at one end only being free to expand and contract at the other end. The illustration shows the course of the cooling water, first through the inner tubes and then through the annular spaces between the inner and outer tubes.

the air and non-condensible vapors through the outlet B, to the air pump. Space should be left below the lower tubes so that the water of condensation cannot come in contact with them and thus become chilled. The circulating or cooling water enters through the inlet C, into the chamber E, traverses the inner and outer tubes into the chamber F, thence through openings into G, then through the upper group of tubes, and is discharged through the outlet H.

In the single tube type, fig. 5,662, the cooling water enters at, A, being directed by the baffle, passes through the lower group of tubes to Chamber C, thence through upper group of tubes D, and out through E.



Figs. 5,664 and 5,665.—Stuffing boxes for lace packing for the tube ends. This requires a recess in the tube plate around each tube opening tapped for reception of a screwed gland that slips over the tube end, compressing the packing into the bottom of the recess. It is simply a small stuffing box. The outside end of the gland is sometimes contracted, thus preventing the tube crawling out of the tube plates. The gland packing is expensive and somewhat tedious to make, but proves in the end the most durable and lasting variety. With this kind of joint the condenser is always ready for operation, even after long laying up. The tube plates are now almost universally of brass, thick enough to afford a good bearing for the tubes and their packing, and strong enough to stand the excess pressure of the atmosphere without deflection. For large tube plates stays may be necessary to secure the needed rigidity.

The spacing of the tubes is important with respect to the efficiency of the cooling surface.

The old conception, which regarded a condenser merely as "a box full of tubes," resulted in the construction of condensers with tubes so closely spaced as to seriously impede the flow of the steam.

In a properly designed condenser the pressure drop from the exhaust steam inlet to the air pump connection is very slight, whereas in a poor design, it may amount to an inch or more of vacuum.

The shell of all condensers must resist the excess pressure of the atmosphere above the vacuum, and, for this purpose, must be tight and rigidly strong.

It is usually of cylindrical section, but when box shaped, the flat surfaces must be stiffened by ribs to prevent collapse.

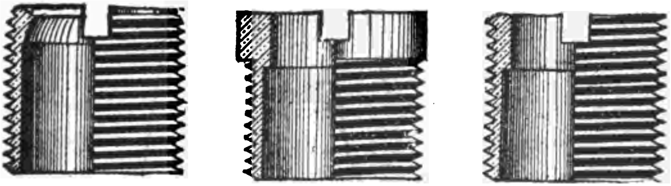
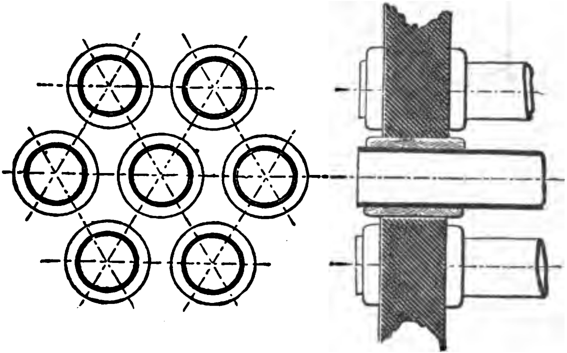


Fig. 5,666 to 5,668.—Three styles of screw gland for packing the tubes of surface condensers.



Figs. 5,669 and 5,670.—Details of wooden ferrules for condenser tube end packing. The wood consists of a small, soft, wooden sleeve, which is pushed into the smooth hole of the tube plate, over the tube end, in a compressed condition. After being wet by the steam and water, it swells considerably, thus clamping the tube tightly on the inside, which pressing strongly against the tube plate. Outside of the tube plate, where free to swell, it should form a slight collar around the opening. With sufficient previous compression, the wood sleeve proves amply able to preserve a tight joint. It has the advantage of being cheap, easily made and quickly applied, but it is apt to give trouble after the condenser has been laid up for a long period.

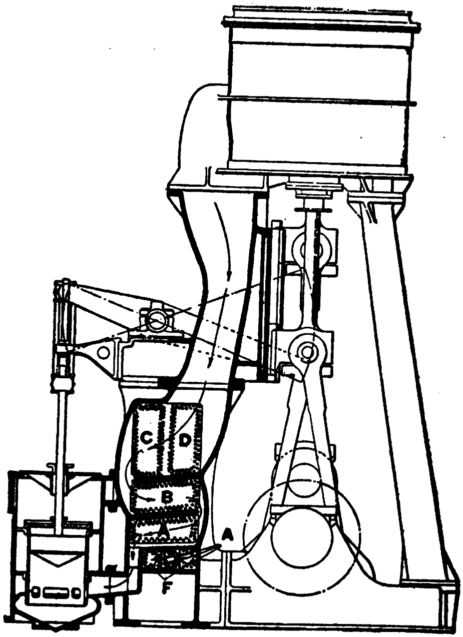
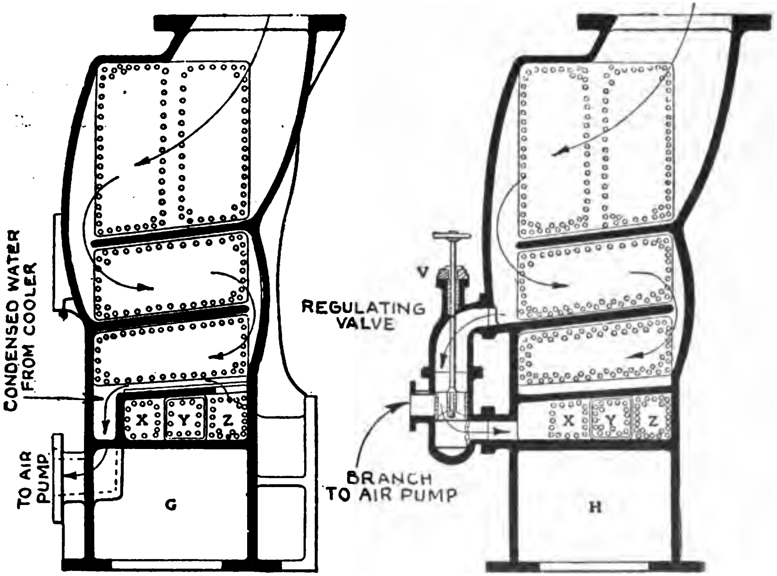


FIG. 5,671.—Built in *contra-flow* surface condenser with direct connected Edwards air pump. The condenser is built into the frame work of the engine as shown. The condensing tubes are arranged in compartments, as shown. The steam coming from the engine cylinder follows the path indicated by the arrows through the upper nest of tubes in an even flow over the entire length of each tube, and at right angles to them. As the steam reaches the upper tubeless chamber it reverses its direction of flow, because of the upper baffle plate, and passes over the second bank of tubes, reversing again in the next lower tubeless chamber and passing over the third and lowest nest of condensing tubes. As the tubeless chambers have ample area, the change in the direction of the flow of steam is not sudden. From the lowest nest of tubes the water of condensation passes to the air pump, changing its direction of flow for the last time in the tubeless space in the bottom of the condenser base. By this successive passing of the steam over all the tubes in one compartment, and again being uniformly distributed in the tubeless chambers already referred to, each tube is made to do a proportionate amount of work. The efficiency of the tubes is also increased because the steam in zigzaging down over the several nests of tubes increases its distance of travel, which increases the efficiency of the condensing surface. The cooling water enters the lower nest of tubes A, and, passing through the horizontal cooling tubes, reverses its direction of flow at the other end and returns through the nest B, reversing again and passing through the nest C, to the other end of the condenser where it again reverses and returns through nest D. The cooling water is then discharged from the condenser. Accordingly the hottest water and hottest steam are brought in contact with the cooling tubes at the top, while the coldest water and coldest steam are brought in contact with the cooling tubes at the bottom. Each baffle plate carries off the condensate from the tube nest above, hence the condensate does not have to fall over all the tubes and accordingly the efficiency is increased.



Figs. 5,672 and 5,673.—Sections through contra-flow built in condenser illustrating cooling chamber operation. ***In order that*** the air pump may extract the greatest quantity of air from the condenser, the temperature must be low relatively to the temperature of the condenser, for to remove a given weight of air it is necessary to remove the vapor with which the air is mixed. In this instance a cooling chamber has been incorporated in the design of the condenser, which is placed in the bottom, as shown. In case it be desired to obtain the highest vacuum, the entire feed water can be cooled down before passing into the air pump. On the other hand, when it is desired to maintain a fairly high thermal efficiency, the amount of water admitted to the cooler can be regulated so as to reduce the amount of water admitted to the cooler and lower the temperature of the air pump discharge sufficiently to obtain just the vacuum desired. The cooler is, therefore, a ready means of increasing the effective capacity of the air pump. The condensate may be passed direct to the air pump or through the cooler by means of the cooler regulating valve. This is made possible by the regulating valve V. In H, the cooler is in three divisions; the condensing water first passes through the division X, entering the end on which is located the regulating valve; it then passes through division Y, and finally returns through Z to the outlet. By this arrangement of regulating the water of condensation and cooling water, the highest temperature of feed water under any given condition, and the ability to maintain the most economical vacuum at all seasons of the year, may be attained; at the same time, the power efficiency of the engine may also be raised to a maximum when desired, by raising the degree of vacuum considerably above the normal.

Frequently surface condensers are built into and form part of the framing and the bed plate of the engine, as shown in fig. 5,671, in which case the shell has facings, lugs or flanges, for attachment to the other parts of the framing.

Where the condenser is independent, lugs, brackets or flanges must be provided for secure attachment to suitable foundations. The inside space is subdivided by baffle plates to guide the steam in its course over the tubes, as in fig. 5,674, the three pass arrangement giving a counter-flow in the upper pass.

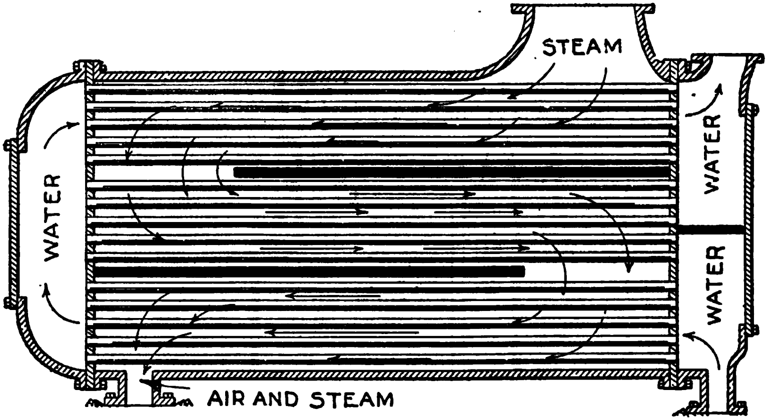


Fig. 5,674.—*Counter-flow* condenser. ***In this arrangement*** the steam flows parallel with the cooling water as indicated by the arrows. The baffle plates cause the entering steam to flow in a direction parallel with the upper condensing tubes; when striking the end of the condenser body, the direction of flow is reversed; this operation being repeated as often as there are baffle plates.

Condenser Tubes.—These are generally made of solid drawn brass and are tested both by hydraulic pressure and steam. They are turned both inside and outside. The standard sizes are ⅝ in. and ¾ in. outside diameter. No. 18 stubs gauge in lengths of 12, 14, 16, 18 and 20 feet.

The Admiralty specify that tubes be made of 70 % of best selected copper, and to have 10 % of tin in their composition, the tubes to be tested to a pressure of 300 lbs.

According to Whitham, the velocity of flow of the circulating water through the tubes should be between the limits 400 and 700 ft. per minute. As given by Marks, the minimum allowable spacing of tubes is as follows:

Outside diameter of tube, ins........	5/8	3/4	7/8	1	1 1/4
Pitch of tubes, ins.................	15/16	1 1/16	1 1/4	1 3/8	1 5/8
Number of tubes per sq. ft. of plate	189	147	106	88	63

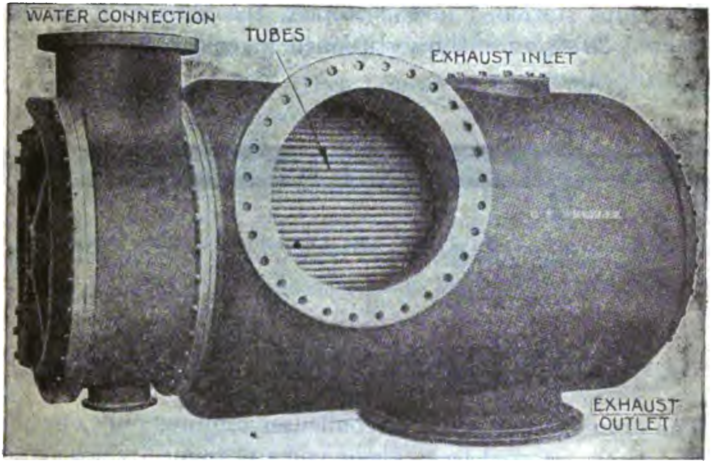


FIG. 5,675.—Wheeler water works condenser. The condensing water passes through the shell and the steam is condensed inside the tubes. It is customary to pass all the water going to the main pump unit through the condenser so that the question of economy in the use of water does not arise in this connection, the chief requirements being to provide the proper amount of condensing surface and to minimize the resistance to the flow of the water. On the latter account the tubes are spaced on wider centers than in the case of the standard condenser, and other provisions are made to insure the minimum possible increase in the head on the main pump. Another important consideration in the design of this type of surface condenser is to insure a negligible vacuum drop between the prime mover and the vacuum pump, which is done by carefully working out for each case the required area of the exhaust steam inlet, the volume of the steam box and the number of tubes in each of the two passes which is given to the steam before the condensate and non-condensable gases and vapors are removed by the air pump.

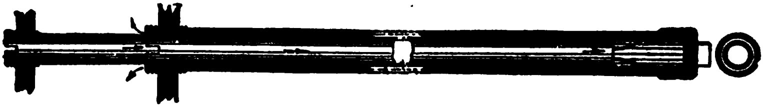
The Cooling Surface.—According to Seaton, in practice with the compound engines, brass condenser tubes 18 B.W.G.

(stubs) thick, a condensation of 13 lbs. of steam per sq. ft. per hour, with the cooling water at an initial temperature of 60° is considered fair work when the temperature of the feed water is to be maintained at 120°.

In general practice the following holds good when the temperature of the sea water is about 60°.

Terminal pressure, lbs. abs. ...	30	20	15	12½	10	8	6
Sq. ft. cooling surface per I.H.P.	3	2.5	2.25	2	1.8	1.6	1.5

For ships stationed in the tropics, the allowance should be increased 20 %; for ships stationed in cold climates 10% less suffices (*Seaton*).



FIGS. 5,676 and 5,677.—Detail of double tube of double tube condenser showing flow of the cooling water through the tubes.

CONDENSER PUMPS

The ordinary low level jet condenser requires only one pump (erroneously referred to as air or vacuum pump) which removes the cooling water, condensate, air and other non-condensable vapors, whereas two pumps are required for a surface condenser, one to circulate the cooling water and one to remove the condensate, air and other non-condensable vapors, the latter being called the wet air pump as distinguished from the dry air pump which removes the air and non-condensable vapors only, a third pump being required to remove the condensate and known as the hot well pump. Dry air pumps are used especially where a high vacuum is required as with turbines.

Jet Condenser Pumps.—The ordinary direct connected double acting horizontal piston pump is generally used for jet condensers, although on some side wheel jet condensing steamers a vertical pump is used. The pump is practically the same as a wet air pump used on surface condensers, differing chiefly in size. Now since the jet condenser pump must handle everything that must be pumped out of the condenser, in order to determine its size, it is necessary to calculate:

1. Amount of steam to be condensed.
2. Amount of water required to condense the steam.
3. Amount of air and other non-condensable vapors to be removed from the condenser.

Each pound of injection water will absorb from the steam to be condensed, a number of heat units equal to its rise in temperature in passing through the condenser, and the number of heat units to be taken out of each pound of steam to cause condensation will be equal to its total heat less the heat in the resulting condensate, that is,

$$\text{Quantity of injection water} = \frac{\text{total heat of steam} - \text{heat in condensate}}{\text{rise in temperature of injection water}}$$

or using the usual symbols,

$$Q = \frac{H - h}{T - t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which

H = total heat in one pound of the steam.
h = heat in one pound of the condensate.
t = temperature at which the injection water enters condenser.
T = temperature at which the injection water leaves condenser.

Now, evidently, since the pump must handle both the injection water and the condensate, the total amount of water to be handled is

$$Q' = \left(1 + \frac{H-h}{T-t}\right) \times W \quad \ldots\ldots\ldots\ldots (2)$$

in which

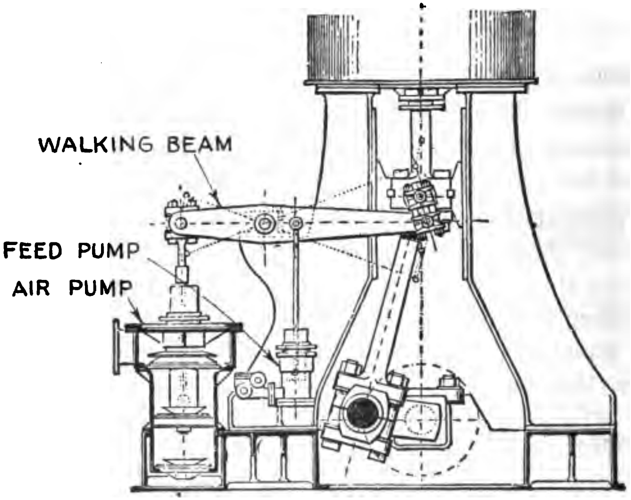
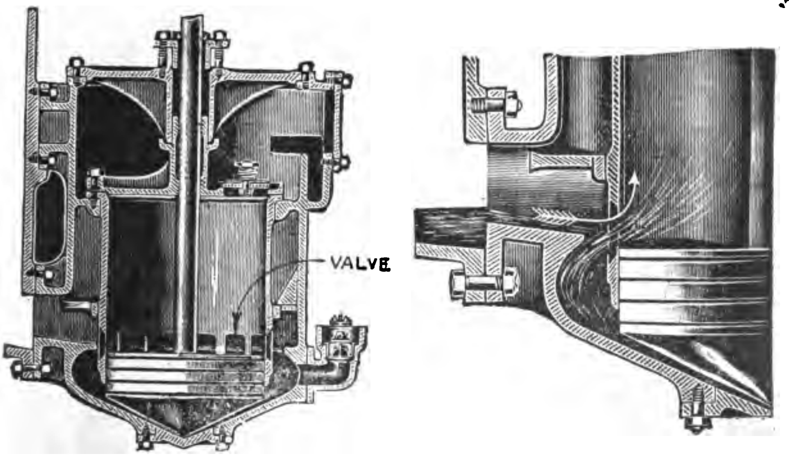


FIG. 5,678.—Rear end view of marine engine showing vertical air and feed pumps driven from cross head of the engine. The walking beams transmit the same number of reciprocations, but reduce the stroke of the pumps by a shortening of the lever on one side of the fulcrum. The beams are built up of steel plates, cast iron bosses and center sleeves, with steel or iron shafts and pins. The fulcrum pins rest in substantial bearings on the framing or foundation while the end pins carry suspension or connecting rods, for connecting to the engine and pump cross heads or trunk pins. ***The points in favor*** of direct connected pumps are: 1, the absence of all steam cylinders, with their working and transmitting gear and multiplicity of stuffing boxes; 2, the great saving of attendance and avoidance of uncertainty of operation; 3, the absence of a complication of piping and considerable space taken up; 4, the application of the power of the main engine to the work of driving the pumps, where it is done at the best possible economy in steam consumption. The author prefers directed pumps to independent pumps in marine plants.

Q' = total *weight* of water entering condenser.
W = Weight of steam to be condensed in lbs.
Water contains mechanically mixed with it $^1/_{20}$ or 5 % of

its volume of air at atmospheric pressure. If P = atmospheric pressure and p = absolute pressure in condenser, then a cu. ft. of water when it has entered the condenser is represented by .95 of a cu. ft. of water and $.5\times P\div p$ of a cu. ft. of air.

Now if Q'' = the total *volume* of water entering the condenser per minute, T_1, temperature of the condenser, T_2, temperature of the cooling water (before entering condenser), then $.95\times Q''$ = volume of water to be pumped from condenser per min. and



FIGS. 5,679 and 5,680.—Edwards single acting *impulse* vertical wet air pump. ***In construction,*** the piston at the low point of its stroke uncovers ports in the cylinder walls, which form an inlet valve; the only other valves are the discharge or head valves. ***In operation*** the condensate flows continuously by gravity from the condenser into the base of the pump, and is there dealt with mechanically by the conical bucket working in combination with a base of similar shape. Upon the descent of the bucket piston "slaps" the accumulation of water in the bottom of the cylinder giving it an impulse, and the momentum thus acquired causes the water and air to flow at high velocity through the ports into the cylinder. Immediately after the rising piston closes the posts and carries the water and air up with it, discharging through the head valves. The arrangement lends itself to high speeds and it is claimed that the elimination of the ordinary type of foot valve gives from ½ to 1 inch better vacuum.

$$.5\times\frac{P}{p}\times\frac{T_2+461^\circ}{T_1+461^\circ}=\text{the quantity of air;}$$

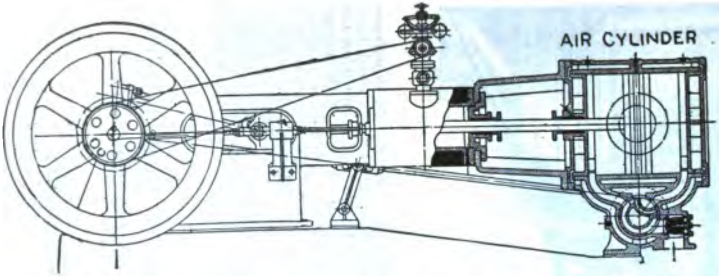


FIG. 5,681.—Wheeler horizontal center crank rotative dry air pump with mechanically operated rocking valve. ***In construction,*** the air cylinder is completely water jacketted that is barrel, head, and valve chamber. The rocking air valve is provided with an equalizing port arranged to connect the two ends of the cylinder at the completion of each stroke after the closing of the suction port, thus almost eliminating the effect of clearances and preventing loss of efficiency which would otherwise result from the re-expansion of the vapors at the beginning of the suction stroke. The discharge valves are of the poppet spring loaded type and readily accessible. All valves are located underneath the air cylinder to insure draining. The inlet valve or valves are driven from the crank shaft by means of eccentric and rod operating a crank on the end of the valve rod. The valve chamber is cast integral with the air cylinder and has accurately fitted ports for the reception of the mechanically operated valve. The arrangement of the poppet discharge valves should be noted. These are spring loaded pressed steel cylinders of light construction, but of ample strength; and a double valve arrangement is adopted, whereby, in the event of a small quantity of entrained water entering the cylinder, a large extra valve opening is obtained, permitting the water to be freely discharged without injury to the pump. A vacuum of .25 inch of the barometer is claimed for this pump.

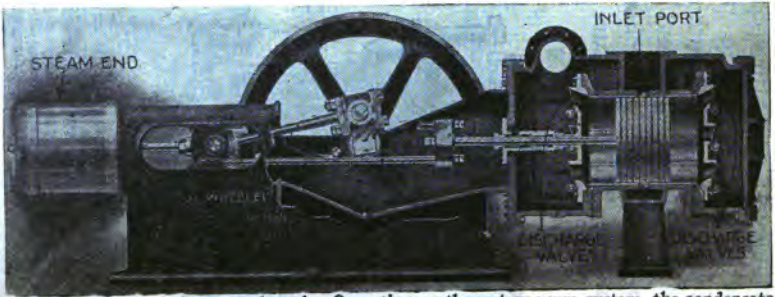
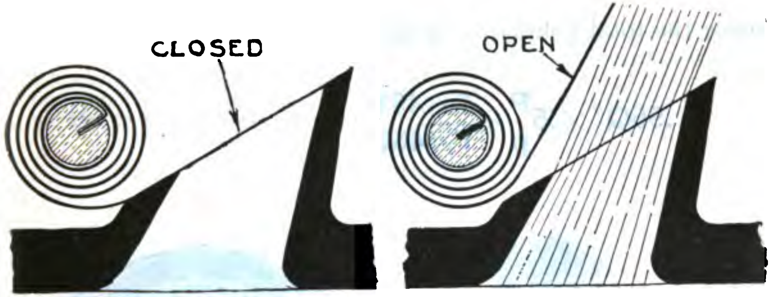


FIG. 5,682.—Mullan uniflow or so-called "suction valveless" double acting displacement wet air pumps with Guthermuth discharge valves. ***In operation,*** the piston creates a vacuum at each stroke until near the end of its travel, it uncovers a series of ports located around the middle of the cylinder and through which the vapors are drawn into the suction space thus eliminating suction valves and resulting loss of vacuum attending their operation. The Guthermuth discharge valves are mounted on decks bolted to each end of the pump barrel. Operating on the wet vacuum system, the condensate flows into the pump by gravity, entering at the top or side. On the discharge stroke the water rises ahead of the piston, compressing the air until both are forced out through the discharge valves. At the end of the stroke the clearance space is filled with water, preventing re-expansion. There are no pockets in which the air can collect, so that (as claimed) a vacuum within a fraction of an inch of the theoretical can be maintained.



Figs. 5,683 and 5,684.—Gutermuth flexible metallic valve for air pumps. Fig. 5,683, valve in closed position; fig. 5,684, in open position. ***It consists of*** a strip of phosphor bronze or special steel of high tensile strength and elasticity, coiled at one end as shown, the other end being left flat to serve as the valve. The inner end of the coil is held in a slot of the valve stem, the latter being secured in position by means of a ratchet and then locked. The valves are usually mounted in groups on a bronze valve stem, which holds them against the seat. Provision is made for adjusting this rod, whereby the desired tension can be put on the valves. The Gutermuth valve is quite similar in practice to the hair spring in a watch; both equally elastic and required to withstand coiling and uncoiling countless millions of times. The distinguishing feature of the Gutermuth is the fact that is may be opened to any angle without straining the material; *i.e.*, the elasticity of the entire length of the coil is pressed into service and without friction, insuring positive action without guides or guards, as the valve will always return to its original position on the valve seat. With the lifting from its seat the valve has also a wiping motion, which distinguishes it from all other valves. This action assists in the smooth and silent operation of the valve. Another advantage as claimed of the Gutermuth valve, as compared with the ordinary type of valve, is the fact that no turning of the current takes place and no eddies are formed, air and water passing through the port without deflection as shown on fig. 5,684.

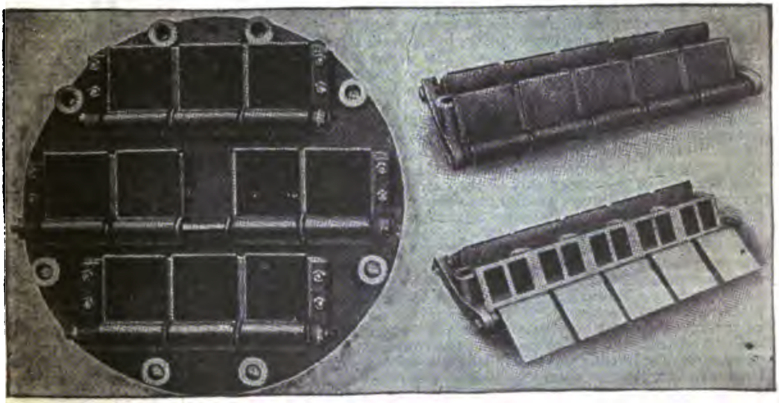
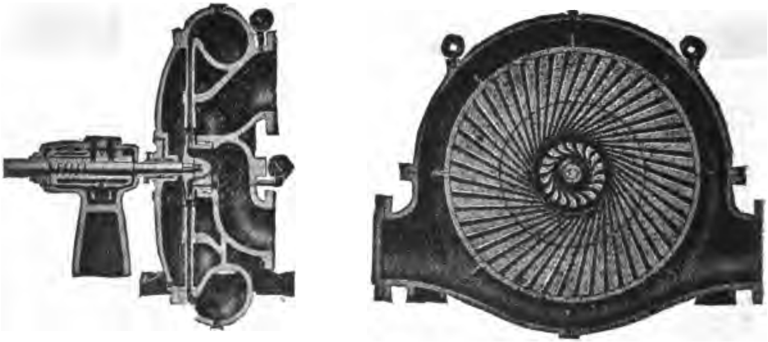


Fig. 5,685.—Valve deck of a Mullan air pump with Gutermuth valves closed.

Figs. 5,686 and 5,687.—Rotrex air pump valve deck with Gutermuth valves. Fig. 5,686, valves closed; fig. 5,687, valves wide open.

hence the total volume to be abstracted per minute is:

$$.95Q'' \times .5\frac{P}{p} \times \frac{T_2+461^\circ}{T_1+461^\circ} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$



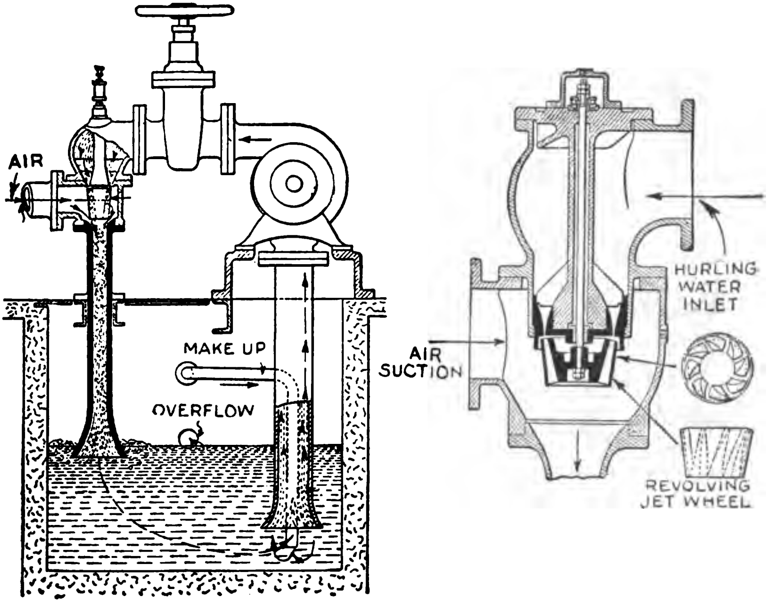
FIGS. 5,688 and 5,689.—Alberger centrifugal entrainment air pump. Its operating principle is *to use intermittent pistons of water to expel air and thus produce a vacuum.* The moving element is a high speed enclosed impeller of special design, which draws water from the source of supply, and hurls it, at high velocity, in separate streams, across an air gap into a number of compression or diffusion chambers. The vanes which form the diffusion chambers are so designed that they cut the streams of water into a large number of layers, or pistons, which entrap successive portions of air. These pistons of water, moving at high velocities, compress the air to atmospheric pressure, and the mixture of air and water passes through an annular chamber to the discharge opening of the pump. The casing is of cast iron, annular in form. Bolted to it is a cast iron cover plate, forming an annular recess to hold the diffuser in position, and containing a deep water sealed stuffing box. A special feature is that both the casing and the cover plate are divided on the horizontal center line, which permits the easy removal of the upper part of the casing for examination and repair. The diffuser is of bronze, finished all over, special care being used to reproduce accurately the form of vanes and passages required to give the maximum air handling capacity with a minimum expenditure of power. The tips of the vanes are most subject to wear and are therefore made integral with a removable side plate. The impeller is of bronze and the shaft of steel bronze covered where in contact with water. The shaft is extra large for the service, and is provided with marine type thrust collars, and a flexible coupling for connection to the driving power. A heavy water cooled pedestal bearing is mounted with the pump directly on a cast iron baseplate, which is extended to receive the driving power. The bearing is of the ring oiling type, with removable split bushings, and has incorporated in it a multi-collar marine type thrust with an adjusting device to maintain the rotating element in the correct lateral position. In cases where the hurling water contains much foreign matter, or grit, which cannot be removed by a strainer, it is necessary to supply a tank for clean hurling water, so arranged that the water can be used over and over, and so designed that the air will be liberated. Since the re-use of the same water will in time heat it up to a point which will reduce the air handling capacity of the pump, it is necessary to use a hurling water cooler, or furnish a cold make up supply in sufficient volume to keep the temperature of the hurling water within a few degrees of the temperature of the entering condensing water.

Example.—A 100-horse power marine engine requires 30 lbs. of feed water per horse power per hour. If the pressure in the jet condenser be 2 lbs. absolute (25.85 ins. vacuum), how much injection water is required and what size pump if the initial temperature of the injection water be 60° and the final temperature 110°

Total steam to be condensed per minute, or

$$W = \frac{100 \times 30}{60} = 150 \text{ lbs.}$$

Since from the steam table the total heat in 1 lb. of steam at 2 lbs.



FIGS. 5,690 and 5,691.—Worthington "spiro-hurling" entrainment air pump. ***In operation,*** it removes the air and non-condensable vapors from the condenser by hurling jets of water at high velocity approximately rectangular in cross section from a revolving wheel, the water jets rushing through the discharge cone and diffuser in the form of a helix enclosing the vapors which enter around the transforming wheel between the jets or pistons of water. The figures illustrate very clearly the construction and principle of operation. The hurling water is delivered under pressure by a centrifugal pump, taking its supply from a tank into which the air pump discharges. Make up and overflow connections are provided as shown.

absolute pressure is 1,115 *B.t.u.*, and the heat in the condensate 94 *B.t.u.*; substituting in (2)

$$Q' = \left(1 + \frac{1{,}115 - 94}{110 - 60}\right) 150 = 3{,}213 \text{ lbs.}$$

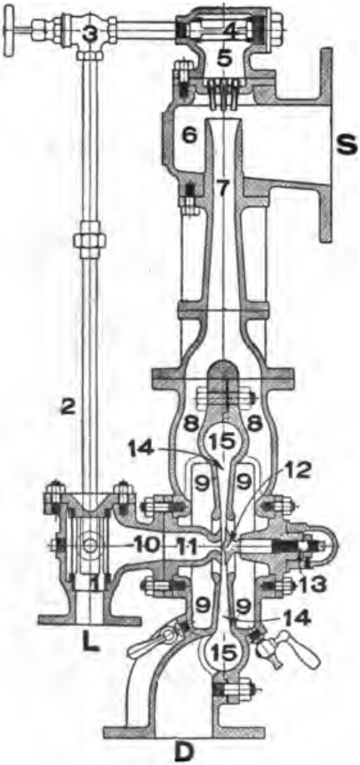


FIG. 5,692.—Wheeler "Radojet" *steam jet* or *ejector* dry air pump. Its principle is the use of *jets of steam for the removal of air*. ***It consists of*** two steam ejectors working in series; that is, in two stages, the upper ejector being the *first stage* and the lower, the *second stage*. Live steam is delivered from a source not shown through opening L, through strainer 1, pipe 2, auxiliary steam valve 3, strainer 4, expansion nozzles 5, across suction chamber 6, of the first stage ejector, which is in communication with the condenser through the suction opening S. ***In operation,*** the steam expands in the nozzles, leaving with a very high velocity, and while passing across suction chamber 6, entrains the air and vapors to be compressed. The mixture passes into the diffuser 7, from where it is discharged at higher absolute pressure than that of the air entering at S, into a double passage 8, communicating with the suction chambers bers 9, of the second stage. These two suction chambers 9, are annular, giving the commingled fluid a large entrainment surface. Steam is simultaneously delivered through the strainer 1, into passage 10, which communicates with the annular expansion nozzle formed between two circular discs, 11 and 12. Disc 12, may be adjusted toward or away from disc 11, by the adjusting screw 13, to vary the cross section of the nozzle passage, thereby changing the expansion ratio of the steam. The steam delivered radially by the annular nozzle 11 and 12, expands, leaving it as a jet of high velocity in the form of a sheet, and in passing across the suction chambers 9, entrains the commingled air and steam coming from the first stage and carries them into the annular diffuser 14, thereby compressing the mixture to atmospheric pressure and discharging it into casing 15, which has the discharge opening D.

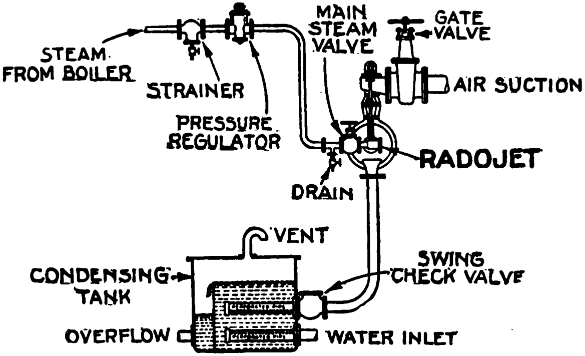


FIG. 5,693.—Wheeler "Radojet" *steam jet* or *ejector* dry air pump and connections. On the steam line is a strainer, pressure regulator drain and main valve as shown, and a check valve on the discharge end. The mixture is discharged into a small tank supplied with fresh water for boiler feed. The steam contained in the mixture is condensed in the tank and the heat transmitted to the boiler feed water, thereby raising its temperature. The air frees itself from the water and escapes through a vent to the atmosphere. If an open feed water heater be used, the discharge is led directly into it, thus utilizing the heat from the jet steam.

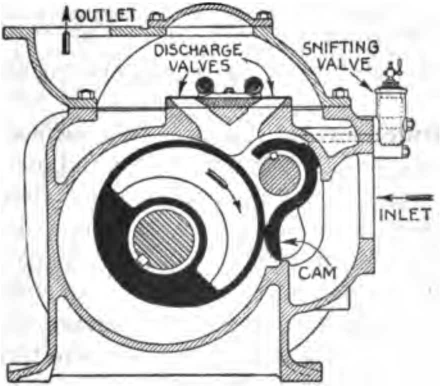


FIG. 5,694.—Wheeler *rotary* air pump. It operates at speeds rendering it suitable for direct connected engine and geared or direct connected motor drive. ***In construction,*** the cylindrical rotor is mounted eccentrically on a shaft supported in outboard bearings. An oscillating cam, operated from the rotor shaft by means of external cranks and connecting rod, separates the suction and discharge sides of the pump cylinder, and follows the motion of the rotor with a small clearance. The rotor is so adjusted as to maintain during its entire rotation a close clearance with the inside of the air cylinder. Air is drawn through the intake, at the lower right, and discharged through the valves shown on the deck above the cam. The outlet is at the top and may be either right or left hand. Freedom from leakage is assured because all clearances are water sealed. The rotor is at no time in contact with the cylinder, nor does the cam touch the rotor, being controlled in its motion by an external driving gear which keeps it close to, but not quite touching, the rotor. One end of the rotor shaft has a crank operating another crank on the end of the oscillating cam shaft, by means of a rod.

The weight of water at 110° being 61.89 lbs. per cu. ft., then its volume at 110° or

$$Q''=3{,}213\div 61.89=51.91 \text{ cu. ft.}$$

95% of which is water and 5% air. Hence the total volume to be abstracted from the condenser per minute is, taking the temperature of the condenser at 120°:

$$.95\times 51.91+.5\times\frac{14.7}{2}\times\frac{60+461}{120+461}=52.62, \text{ say } 53 \text{ cu. ft.}$$

Now the usual practice is to use a pump having a displacement of twice the volume to be pumped, that is, to let the pump fill half full of water, the remainder being occupied by the expanded air. Accordingly, given displacement is

$$53\times 2=106 \text{ cu. ft. per minute}$$

The normal piston speed should be about 100 ft. per minute, hence area of piston $=106\div 100=1.06$ sq. ft., or $1.06\times 144=152.6$ sq. ins.

$$\text{drain of piston corresponding}=\sqrt{\frac{\text{area}}{.7854}}=\sqrt{\frac{152.6}{.7854}}=13.9, \text{ say } 14 \text{ ins.}$$

and the length of stroke will depend on the number of strokes per minute, which, for say 60 strokes per minute, is

$$100\div 60=1.66 \text{ ft. or } 1.66\times 12=19.9, \text{ say } 20 \text{ ins.}$$

Surface Condenser Air Pump.—In a surface condenser the pump has to handle only the condensate and air, the cooling or "circulating" water being pumped by the circulating pump. As compared with a jet condenser, the pump handles a much smaller quantity of water and a relatively large volume of air. The latter item is important because the air volume to be displaced is much larger than the water volume. The air entering by leakage is uncertain and may be 3 or more times as much as was liberated by the water.

Since the pressure in the *l.p.* cylinder of the engine is most of the time below atmospheric pressure, considerable air may leak in through the stuffing boxes unless they be tight. The practice of some pump companies is to give the air pump a displacement equal to 20 times the volume of the condensate, if it be a horizontal double acting pump, and 12 times if vertical single acting.

According to Whitham the usual practice is to make the air pump for a surface condenser one half the capacity of one required for a jet condenser. This will enable the surface condenser to be used as a jet condenser in case of emergency. The air pump should *always* be placed below the condenser for best results (though this is not always possible with keel condensers), and the delivery valves should be water sealed.

Classification of Air Pumps.—The steam turbine with its high vacuum requirements has resulted in a marked development of condenser air pumps, resulting in a multiplicity of types, some of which are very efficient.

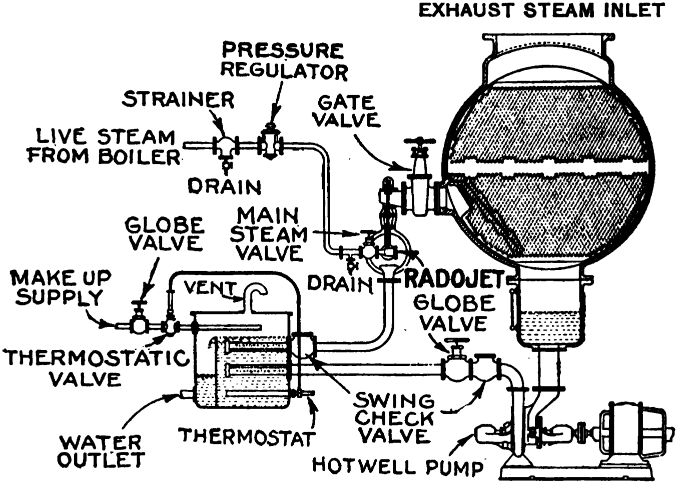


FIG. 5,695.—Sectional view of a surface condenser showing arrangement of motor-driven condensate pump and one or more Wheeler steam jet or ejector air pumps with connections to condensing tank arranged for thermostatically controlled feed water make-up.

In general air pumps may be classified

1. With respect to the duty they perform, as

   a. Wet.
   b. Dry.

2. With respect to the mode of operation, as

a. Direct connected.
b. Independent.

3. With respect to the principle of operation, as

a. Displacement.
b. Impulse.
c. Entrainment.
d. Jet or ejector.

4. With respect to the mechanical features, as

a. Plunger.*
b. Piston.*
c. Single acting.
d. Double acting.
e. Horizontal.
f. Vertical.
g. Centrifugal.
h. Rotary.
i. Jet.

The earliest pumps and the kind largely in use at present where ordinary vacuums are employed are of the displacement type, where a plunger or piston displaces the atmosphere, thus creating a vacuum.

Fig. 5,696 shows the latter type as generally furnished with marine engines where the pumps are direct connected, that is, operated by the engine.

The dry air pump, as commonly constructed, is a direct steam driven reciprocating unit, with its air cylinder and valve mechanism designed to reduce as far as possible the return to the condenser of the compressed air from the clearance spaces. When it is realized that the air expanding back from the clearance will exceed many times the original volume, it becomes evident that the reciprocating type is not the ideal air pump for highest vacuums.

To overcome this defect, the author designed a reciprocating air pump with practically zero clearance for his marine engine (see Chapter 52).

In order to overcome the inherent defects just mentioned, *builders have resorted to other operating principles*, such as *entrainment*, *spiro-heating jet ejection*, etc. These are illustrated in the accompanying illustrations.

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* NOTE.—The author objects to the erroneous yet common misuse of the terms *plunger* and *piston*.

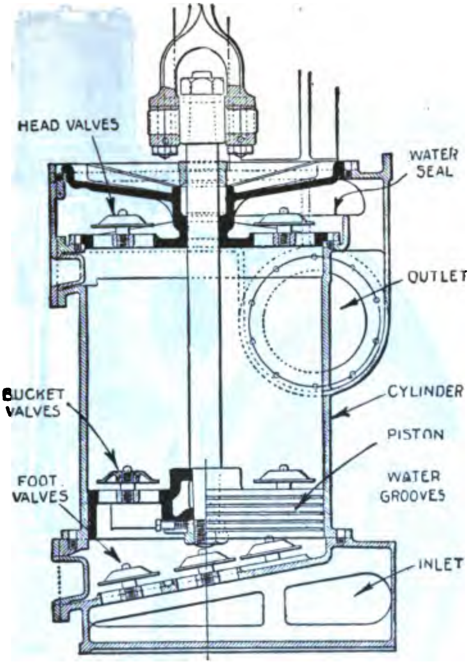


FIG. 5,696.—Vertical single acting direct connected bucket piston wet air pump. The suction channel way is arranged at the lowest part of the condenser, so that the water can be readily and completely removed from it. It is often a part of the condenser shell or otherwise bolted to it; and, being usually of cast iron, must be strong enough to withstand the full atmospheric pressure. As it usually supports the foot valves, all joints and valve seat division plates should be fitted in a thoroughly air tight manner. The barrel or cylinder connects generally to a flange or facing of the channel way, and is constructed in composition or cast iron, with composition sleeve tightly rolled in. It is bored truly cylindrical on its working face, with slight recesses at top and bottom, similar to a steam cylinder, for the over running of the piston or its rings. For quick access to the bucket or foot valves, a hand hole cover is often fitted above or directly in the bore of the barrel, in order to avoid dismounting the top cover and head valves—a great saving of time and labor to the engineers. The delivery channel is sometimes cast on to the barrel, or together with the cover, is bolted to the top flange of the barrel. It holds the head valve seat, which, however, is also found independent and bolted directly to the top flange of the barrel. Cast iron is extensively used for it, although the United States Navy requires composition. The vertical extension for the accumulation of the discharge water serves to water seal the valves to prevent air leakage. Rubber valves are generally used except in the Navy, where metal is employed. Rubber valves are light, open readily, and make a good, tight joint, but, since mineral oil is used in engine cylinders for lubrication, the ordinary rubber deteriorates under its influence, and repairs are liable to be frequent. On account of their greater durability, metal valves are employed. Also hard rubber or fibre valves justly enjoy a certain popularity, as being much more durable than those made of soft rubber. In form the valves are either single rectangular flaps, which lift up on one edge against a curved metal guard, or are formed by several smaller circular valves, rising bodily from their seats. To secure a quick closing, springs of bronze wire are

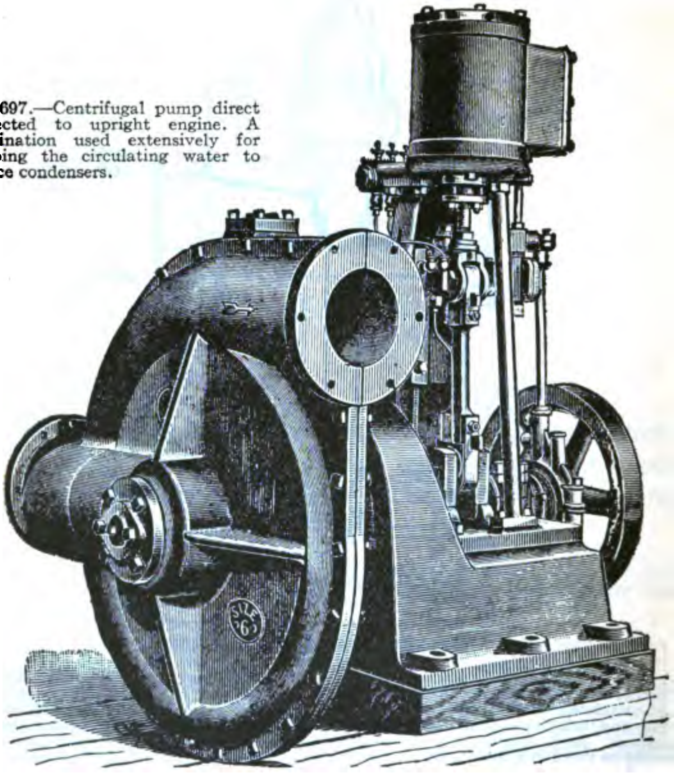


Fig. 5,697.—Centrifugal pump direct connected to upright engine. A combination used extensively for pumping the circulating water to surface condensers.

Fig. 5,696.—*Text continued.*

sometimes fitted on them. The valve seats are usually independent and constructed of composition. For the round valves a central stud keeps the valve in place, allowing only lifting movements, which are limited by a guard at the top of the stud. The flap valves are clamped to the seat on the stationary edge by their curved guards. The piston or bucket of the air pump is actuated either by a solid piston rod, or by a hollow trunk, made entirely of composition, or covered by a composition sleeve. The piston rod type must have a connecting rod and guides above the top cover, while the trunk type contains the connecting rod bearings in the trunk near the piston, and requires no extra guides. The bucket carries the bucket valves, which allow the air and water to pass to the delivery side. The tightness of the bucket against the side of the barrel is secured by a very broad, solid piston, with water grooves to stop leakage, or, more commonly, by packing. This packing may consist of one or more split metal packing rings, bearing, by their elasticity, against the walls, or of fibrous or soft material, held in place and compressed by a bolted follower ring. A stuffing box is provided in the top cover for water tight passage of the piston rod or trunk. With the large diameter of the trunk the depth of the stuffing box should be ample, as the packing cannot be compressed as uniformly as around a small rod.

CHAPTER 86

EVAPORATING AND DISTILLING APPARATUS

On shipboard the fresh water required as "make up" for boiler feed, and for drinking, cooking, etc., is obtained by evaporating the sea water and distilling the vapor by a form of condenser. The plant for this work consists of an evaporator, distiller, and the necessary pumps which are: evaporator feed pump, brine pump and a pump for circulating the condensing water through the distiller.

Ques. What are the functions and construction of the evaporator and distiller?

Ans. The evaporator evaporates salt water into steam, which is then condensed in the distiller or condenser to fresh water. It can then be used for drinking, boiler feeding and other purposes for which salt water could not be used.

The reason for fitting evaporators in ships is because of the loss of fresh water by leakage. This fact requires that an additional supply of feed water be obtained either by carrying a supply in tanks or gaining it in the evaporator. In modern installations a certain amount of the product of the evaporators is aerated and used for culinary purposes.

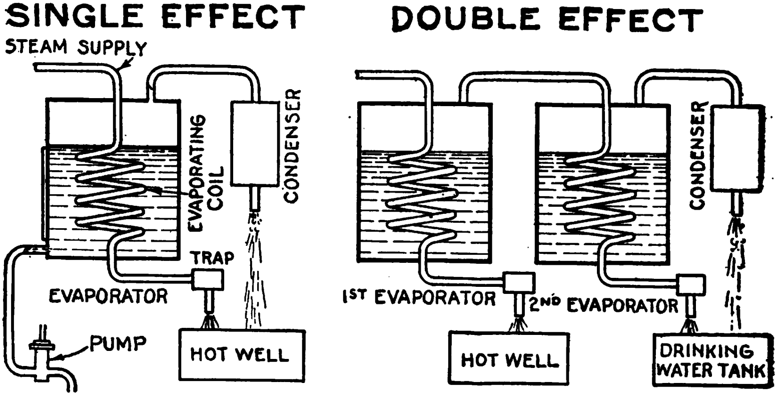
The evaporator is a small boiler, consisting of shell and heads and with steam and water space. The salt water it contains is heated, not by fire gases, but by steam from the boiler or one of the main engine receivers. This water circulates through an internal system of pipe coils, until condensed and drawn on to the condenser.

The steam thus generated, if of fairly high pressure, may be employed in a second evaporator, thus securing a double effect.

For boiler feeding, all the condensed water and low pressure steam is led to the condenser, from which point the air pump delivers it, in form of water, to the hot well.

If the evaporator steam is to be used for production of drinking water it is led first to a special nozzle system called the aerator, where air is mingled with it to make the water drinkable. From the aerator it passes through tinned condenser coils, cooled by circulation of sea water, into a filter, or storage tank, ready for use.

Through the evaporation of the salt water a very strong deposit of salt is thrown down upon the heating coils, which must be removed frequently for the efficiency of the heat transmission.



Figs. 5,698 and 5,699.—Elementary evaporators illustrating *single* and *double effect* evaporation as described in the text.

Some constructions provide for an easy removal of the whole coil system, while others crack the scale off by sudden contraction of the hot coils by cold water and removal of the scale from the bottom through man and hand holes.

Evaporators are fitted in the same manner as boilers, with steam gauge, safety valve, stop valve, water gauge, feed check, bottom blow valve and salinometer cock.

The Plant in Operation.—The steam from the boilers (at a pressure which should not exceed 30 pounds per square inch) enters the top of the manifold of the evaporator, passes through the tubes, thereby being condensed, and is drained off through a steam trap, thence back to the boiler, carrying with it such heat as may remain.

The salt or polluted water surrounds the tubes and should not be carried at a height that would more than barely cover the top row of tubes; it is vaporized by the passage of the live steam through the tubes and should not be allowed to reach a pressure in shell of over 10 pounds per square inch. The vapor passes over to the distiller, where it is condensed; the resultant water flows to the filter tank, from whence it is pumped or drained to storage tanks.

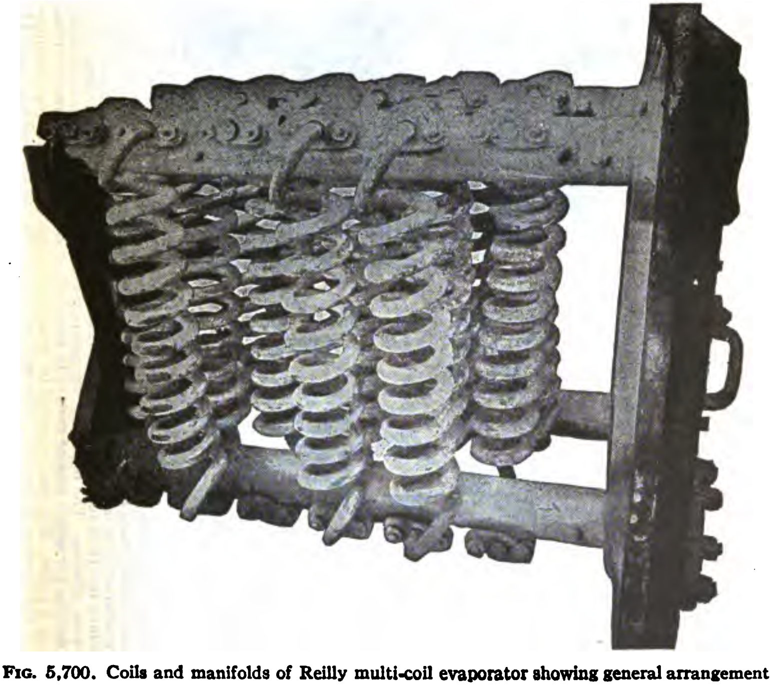
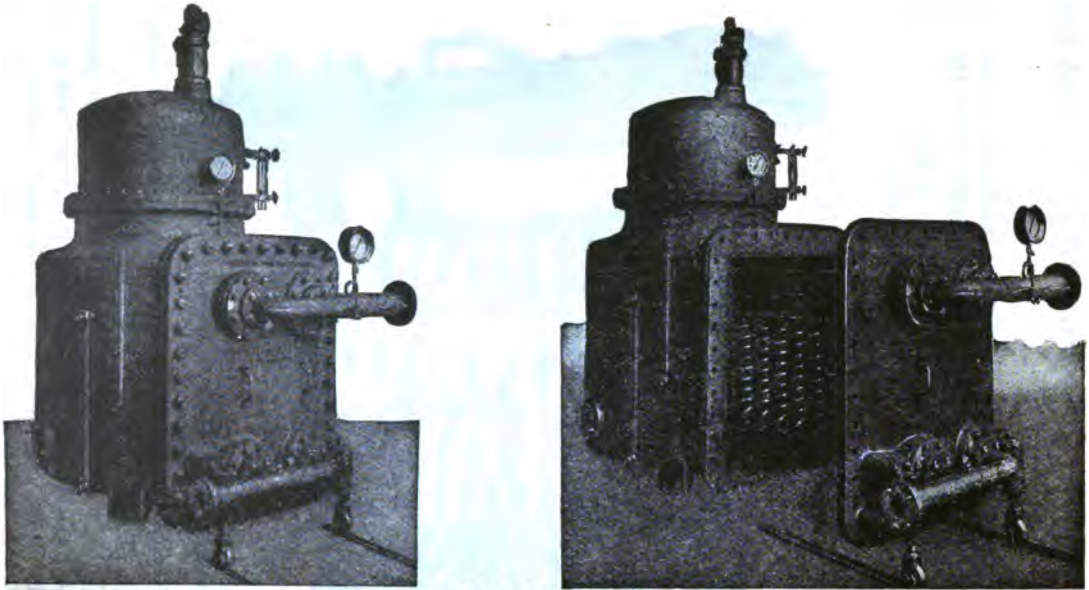


FIG. 5,700. Coils and manifolds of Reilly multi-coil evaporator showing general arrangement.



FIGS. 5,701 and 5,702. Reilly submerged type evaporator in open and closed positions. *In construction,* the shell is of cast iron, steel, copper or composition, depending upon the requirements. In all types the arrangement of coils and internal parts is identical. Standard shells are either of close grained grey cast iron or open hearth boiler and flange steel; doors and frames to correspond. The manifolds to which the coils are attached are of composition or cast iron; coils are of seamless drawn brass tubing, tinned or plain, rolled to shape without filing, in order to secure a uniform thickness of metal throughout. Coil ends are equipped with quick detachable flanged joints, free from brazing, making a metal to metal cone faced bolted joint. Baffles are arranged so as to increase circulation and prevent priming. The manifolds are securely bolted to the door, the coils being bolted to the steam and drain manifolds, thus permitting the entire nest of coils to be removed upon releasing the door. The weight of the door is taken off the studs by means of a jack roller. The door is guided by means of a slotted standard from the upper manifold, engaging with a fixed "T" track attached to the interior of the shell. The weight of the coils and manifolds is carried by composition rollers inside the evaporator. Zinc plates are used in steel shell evaporators, and are conveniently arranged for replacement.

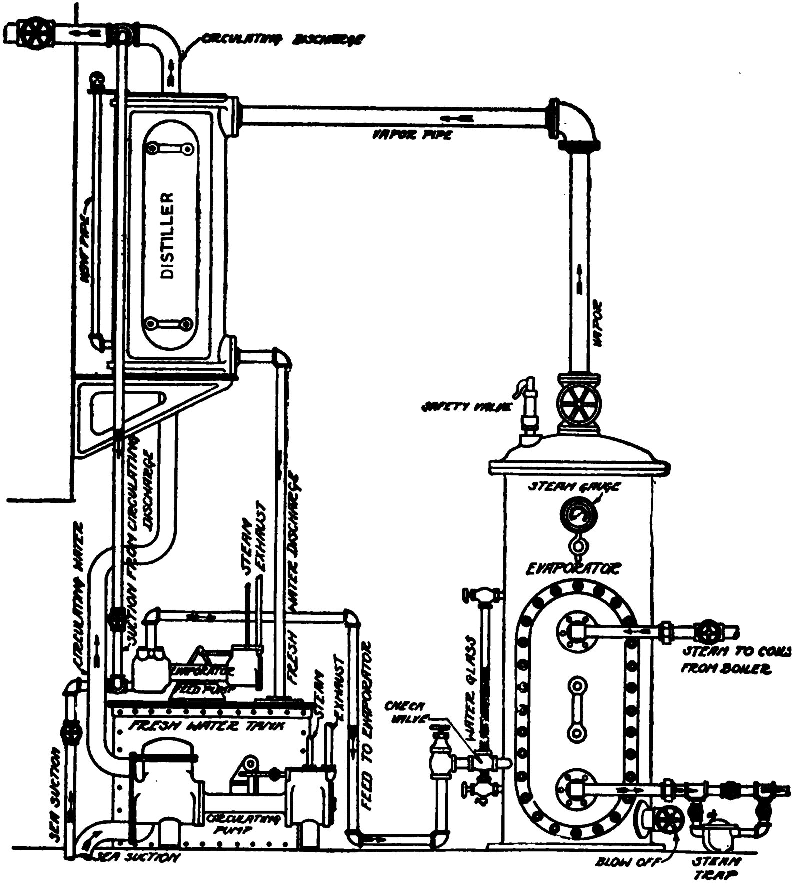
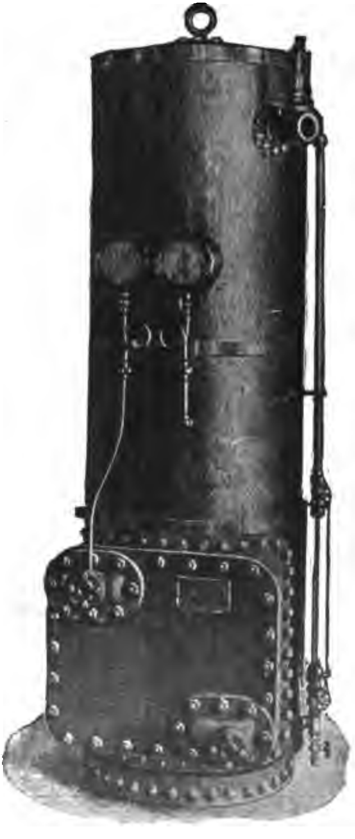


FIG. 5,703. Marine installation of Reilly multi-coil evaporator and distiller plant for feed make up and drinking water. ***It consists of*** evaporator, distiller, aerating filter, circulating pump, feed pump, trap and storage tank. These units may be located wherever desired except that the distiller should be placed as high above the evaporator as possible. The steam for evaporator coils should be taken direct from boiler or auxiliary steam main, and the drain should be led to the trap, which discharges into hot well or filter box. The vapor connection on shell of evaporator should be valved, and led either to feed water heater, *l. p.* receiver, or to main engine condenser; the relative efficiency of the three methods depending upon local conditions. A branch from the vapor pipe should be led to a special distiller for drinking and culinary purposes. The condensed vapor from the coils of the distiller runs by gravity to the aerating filter, and thence to the fresh water tanks. The circulating pump and feed pump may be located wherever is most convenient; but when possible, locate the



The distiller circulating pump forces cold water into the bottom of the distiller, around the steam coils and overboard. As this water in its passage through the distiller becomes warm it is economical to use part of it for evaporator feed.

To Blow Off Brine from the Evaporator.—When a saturation of 5/32 has been reached, with the feed pump running to keep the water at its normal level, start the brine pump and remove the brine, or shut off the boiler steam supply, and keeping the water

FIG. 5,704. ***Davidson*** (Baird patent) evaporator type D. The rated capacity is based on an allowance of heating surface which is greatly excessive when tubes are clean, but this allowance is made so that the evaporator will give its full rated capacity even when tubes are scaled and not fully effective. With clean tubes the capacity given can be greatly exceeded. The shells are made of boiler plate, with dished steel heads both ends; the tubes are of steel or brass (as desired), expanded in sheet steel tube heads, and can be entirely removed by breaking one joint. The steam chest and tubes are tested to 250 pounds pressure and the shell to 50 pounds pressure per square inch. The following fittings are provided: Spring pop safety valve for shell, water gauge with fittings, steam gauge for coils, combined steam and vacuum gauge for shell, steam trap for drain from tubes, feed, blow, and drain valves, and salinometer pot complete with thermometer and hydrometer.

FIG. 5,703. *Text continued.*

evaporator feed pump close to evaporator, so that the engineer may conveniently time this pump according to the water level in evaporator gauge glass. The suction to evaporator feed pump may be taken either from the circulating pump discharge or direct from the sea. The evaporator feed pump discharge may be led directly into the evaporator, or if preferred may be first passed through a small feed water heater, taking its steam supply from the exhaust of the pump. When fitting up the feed pump, provide a branch from its discharge pipe to permit ready connection to steam manifold of evaporator for testing purposes when door is open. This avoids testing the coils with steam. The steam and exhaust to pumps may be arranged to suit conditions. The blow off from the evaporator should discharge overboard, with a suitable check valve at the ship's side. With this arrangement of piping, the evaporator will give the best results.

level at its proper height, wait until the machine ceases to operate, stop feed pump, then open up the brine cock and drain off the brine, then start feed pump and wash out evaporator; or when the evaporator feed pump is connected as shown, it is used to draw off the brine. In any case do not attempt to empty evaporator with steam pressure on the tubes, or a badly scaled evaporator will be the result.

"Making Up" Boiler Feed Water.—When it is desired to use all or part of the water evaporated for boiler feed, connection is made from the evaporator vapor pipe to the main condenser.

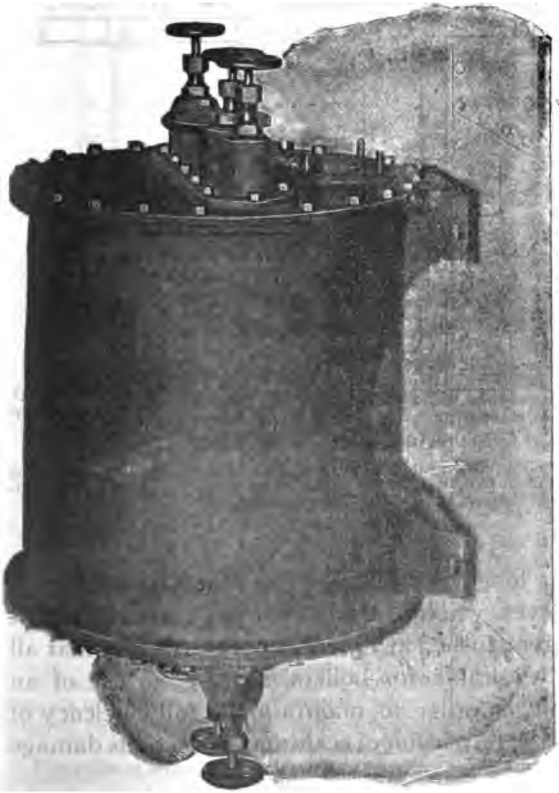


FIG. 5,705. Davidson (Baird patent) fresh water distiller. In connection with evaporators, distillers or condensers are employed to make suitable water for drinking, cooking, etc., the above make being manufactured in regular sizes with capacities from 125 to 5,000 gallons per 24 hours. Shells and heads of distiller are made of cast-iron, or shells of copper, with composition heads and flanges; tubes are of seamless drawn copper or brass, tinned inside and outside, secured in composition manifolds, top and bottom, fitted with valves, by means of which any coil in the machine may be entirely shut off, so that in case of a leak in one coil the others may be used without stopping to remove the defective coil. With each distiller a galvanized iron filter tank and supply of animal charcoal is furnished. The water from distiller flows through the pipe in filter tank to the bottom of same and filters upward through charcoal and is drawn off at opening near top of tank.

It is good practice to evaporate the water thus under vacuum; when this is done the steam pressure in the tubes should be kept as low as possible, and care should be taken, when blowing off by the second method herein mentioned, to close the valve in the vapor pipe, to prevent breaking the vacuum in the condenser.

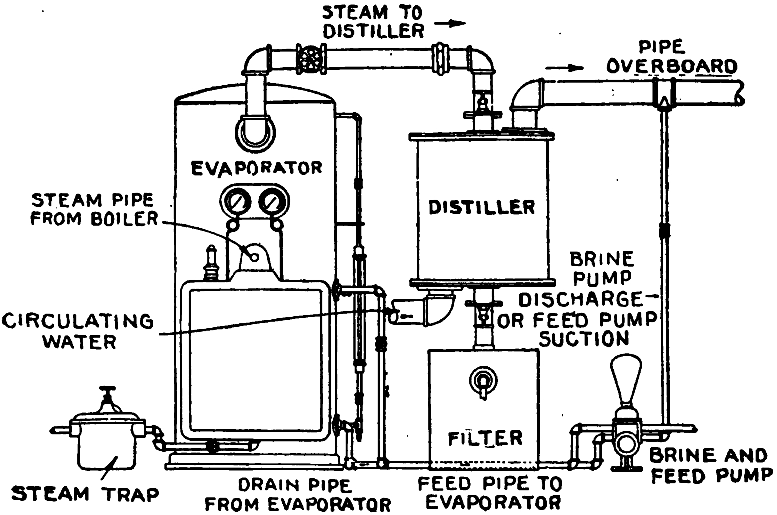
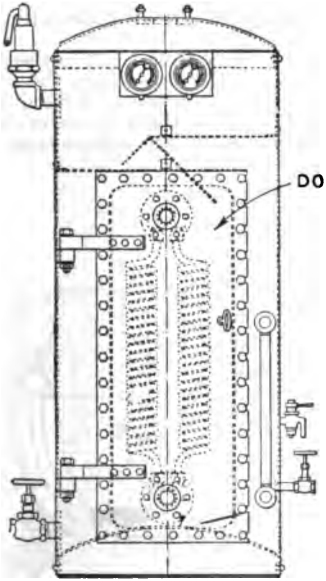
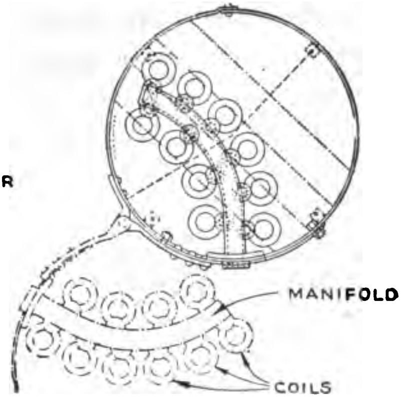


FIG. 5,706. Diagram of Davidson (Baird patent) evaporating and distilling apparatus showing manner of connecting up a plant to make drinking water; all parts are shown except circulating pump; one pump is used for both evaporator feed and brine.

On vessels making long voyages an evaporator is practically indispensable and even where the trip is of such duration that the supply may be replenished at different ports, the fact that all fresh water is not desirable for boilers, makes the use of an evaporator advisable in order to maintain the full efficiency of the boilers, prevent the formation of scale and the serious damage resulting therefrom.

Amount of "Make Up" Required.—The waste of feed water by overflow, blowing of whistle, leaks in the boilers, condensers, stuffing boxes, pipe joints and valves, varies greatly; it is more nearly in proportion to the quantity of feed water used than to the horse power.





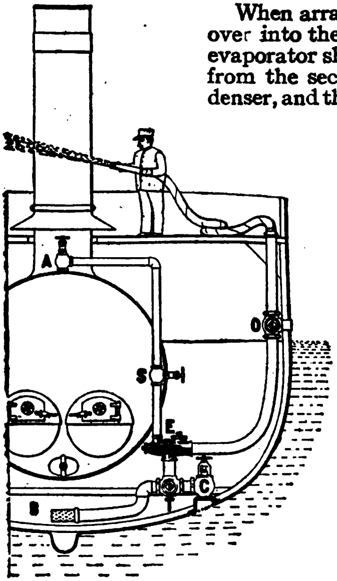
FIGS. 5,707 and 5,708. Row and Davis paracoil evaporator. Fig. 5,707, side view; fig. 5,708, top view showing manifold in open and closed position. Steam of any initial pressure down to atmosphere may be utilized so that evaporator may be operated as a single unit or with multiple effect. In *marine practice* the steam pressure commonly used is from 75 lb. to 100 lbs. *General design*—Consists of shell with door to which is attached an arc type manifold and heating coils, the heating element being mounted on a hinged door which enables same to be swung outside for convenient inspection, cleaning, or repair. A baffle in the top of vapor space is provided to prevent priming. *Shell*—The cylindrical shell and its concave and convex heads are of open hearth boiler steel or cast iron as specified. The side of shell is provided with a large hinged door. *Manifolds*—The top and bottom manifolds for steam inlet and condensation drain respectively are similar at top and bottom; are of cast iron or bronze and bolted to door. *Coils*—These are of seamless drawn copper and are of a form that puts practically no strain on the joints. The helical form also provides for natural contraction and expansion under change in temperatures. This permits the scale to be removed by suddenly flooding the evaporator with cold water and blowing down at intervals, and to a great extent eliminates scaling by hand.

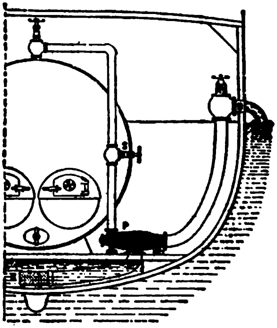
Usually a vessel filled with engines which give a horse power on, say, 16 pounds of feed water will waste less water per horse power than a vessel with engines requiring 40 pounds of feed water per horse power.

Experience shows that this loss will be about 2% of the feed water and the average consumption of water per capita for drinking, cooking and all ordinary purposes, except bathing, is about 2½ gallons per day. The distilling apparatus is always made large enough to supply much more than the amount of water required, to allow for accidents, and also that the full supply may be obtained by running the apparatus a portion of the day.

Double Effect Evaporators.—In battleships and large passenger vessels where the economy of compounding is of sufficient value, the evaporators should be arranged in double effect.

When arranged thus, the vapor from No. 1 is carried over into the tubes of No. 2. The drain from the first evaporator should be led to the hot well, and the drain from the second evaporator led to the fresh water condenser, and there cooled down to be used by the passengers and crew. The generated steam from the second evaporater may either be used as a boiler make up, or led to the condenser or distiller. By compounding the evaporators, a saving of about 30 per cent. of the coal may be obtained.





FIGS. 5,709 and 5,710. Koerting universal bilge syphons. Fig. 5,709 illustrates the use of syphon as a safety appliance on board ships; Fig. 5,710, its use as an emergency bilge pump.

Arrangement of Evaporator.—An evaporator may be arranged in various ways, depending upon the manner in which the vapor generated therein is to be utilized. The three principal methods of using the vapor are:

1. By discharging it direct into the condenser, there to mix with

the condensed steam, and be pumped into the boilers comparatively cold.

2. By discharging it into the low pressure valve casing, so that it does work upon the low pressure piston before being finally condensed with the main body of steam passing through the engine.

3. By utilizing it to heat the main feed water by means of a feed water heater.

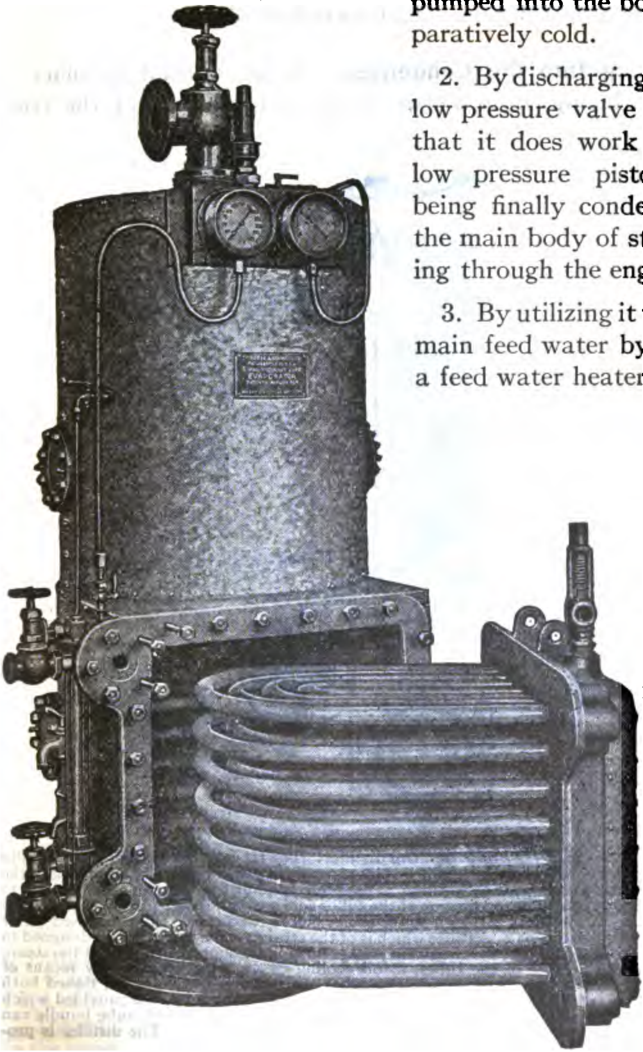
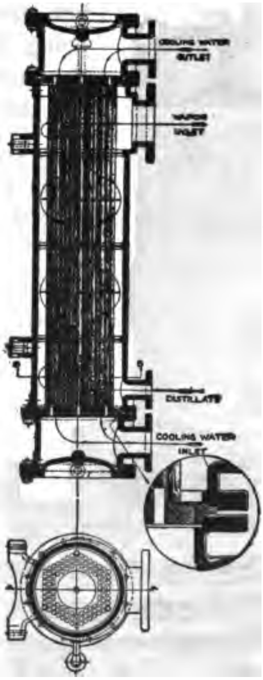


FIG. 5,711. — ***Schutte and Koerting*** **vertical navy type evaporator with brass water chamber and steel vapor chamber; view showing coils removed from evaporator.**

The comparative economy of these different arrangements is given below, and it will be seen that the most economical method of working an evaporator is to utilize the generated steam to heat the boiler feed water.

Evaporating Into the Condenser.—As it is usual to place a vapor or reducing valve between the evaporator and the con-



FIGS. 5,712 to 5,714.—***Schutte and Koerting*** distiller. The fresh water distiller is practically an ordinary surface condenser, which may be placed vertically or horizontally according to the particular requirements from time to time. The steam is admitted through a baffle plate to the outside of the tubes. The top portion of the tubes acts as a condenser for the vapor, while the lower portion of the tubes acts as a water cooler before it passes to the condensed water pump. The figure shows type Z, distiller which is of the straight tube construction designed to be placed in a vertical position, the circulating water flowing through the tubes and the steam passing around the outside of the tubes, a full cooling effect being obtained by means of special baffles shown in the illustration. The tubes are seamless drawn brass, tinned both inside and outside, shells and headers are cast iron. Special arrangement is provided which permits of free expansion and contraction of the tube bundle. The whole tube bundle can be removed for periodical cleaning if this should be found necessary. The distiller is provided with a vacuum breaker.

denser, it may be assumed that evaporation takes place at atmospheric pressure; and the temperature corresponding to this is 212° Fahr.

The water for feeding the evaporator being taken from the circulating discharge, its temperature may be taken at 80° Fahr.

To maintain the density at $\frac{2\frac{1}{2}}{32}$, two-fifths of the total amount of water admitted to the evaporator must be discharged into the bilge, and consequently to produce 1 lb. of pure steam 1⅔ lbs. of water must be admitted to the evaporator; of this, 1 lb. is evaporated and ⅔ lb. discharged into the bilge as hot brine.

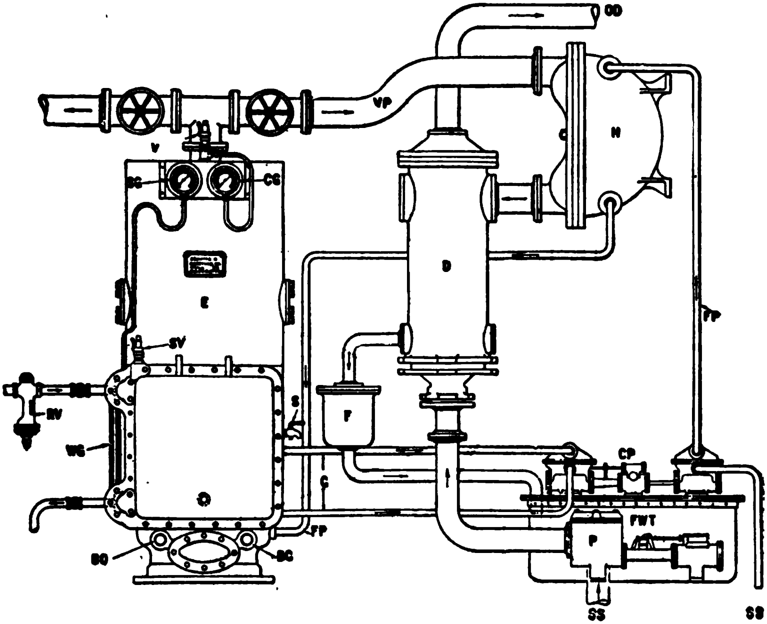


FIG. 5,715. ***Schutte and Koerting*** arrangement of evaporating and distilling plants. ***The parts are:*** E, evaporator; D, distiller; F, filter; H, evaporator feed water heater; CP, evaporator circulating pump; FWT, fresh water tank; SS, sea suction; FP, feed pipe; C, circulating pipe; VP, vapor pipe; P, condensing pump; OD, overboard discharge; V. low pressure safety valve; SG, steam gauge; CG, compound vacuum and pressure gauge; SV, high pressure safety valve; RV, reducing valve; WG, water gauge; S, salinometercock; BO, blow off; BC, brine cooler.

The total heat required to make 1 lb. of pure steam is the sum of the heat in the steam and that discharged in the hot brine.

Amount of heat, in thermal units, in 1 lb. of steam at 212° above 80°........................	1,099	thermal units.
Amount of heat in ⅔ lb. brine at 212° above 80°	⅔ of 132=88	"
Total heat required to make 1 lb. of pure steam, being the sum of the above....................	1,099+88=1,187	"

If it be assumed that 1 lb. of coal will evaporate 10 lbs. of water from and at 212° Fahr., that is, that 9,666 thermal units will be obtained from the combustion of 1 lb. of coal, it follows that the amount of pure steam generated by 1 lb. of coal with this arrangement is

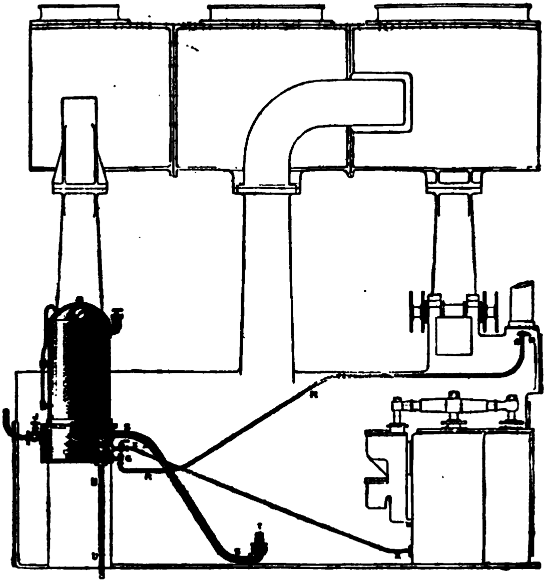
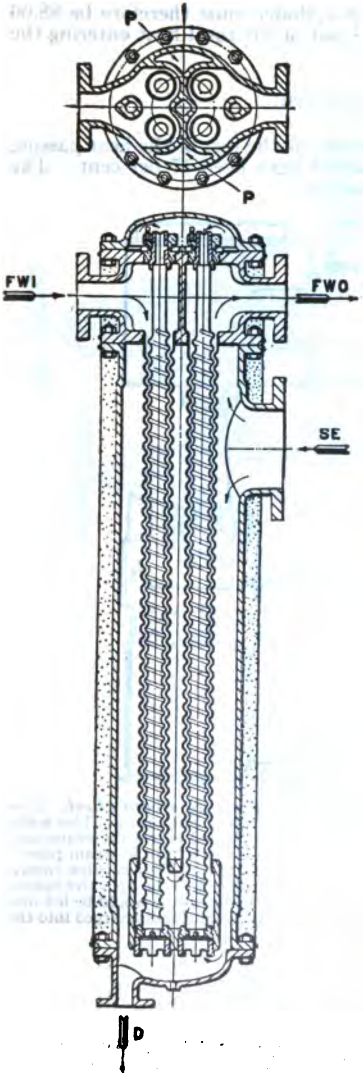


FIG. 5,716. ***Evaporator*** arranged to ***evaporate into the condenser;*** simple but least economical. In this arrangement the steam generated in the evaporator is discharged into main condenser through the pipe S, and reducing valve T. The necessary feed water for the evaporator is taken from the circulating discharge by the pipe R, and enters the evaporator by the non-return valve G. The steam condensed within the coils flows by the pipe X, to the hot well. A pipe U, conducts the brine from the brining cock M, to the bilge. By placing the reducing valve T, low on the condenser, as shown, the steam from the evaporator is allowed to mingle with the feed water, and thus heat it to a slight extent. The amount of heat thus utilized is, however, necessarily small, as it is impossible to raise the temperature of the water above that corresponding to the vacuum in the condenser. With this arrangement, as the water flows into the evaporator by its own weight, it is necessary to place the apparatus as low as possible, so that there may be a considerable head of water.

$$\frac{9{,}666}{1{,}187}=8.14 \text{ lbs.}$$



Consequently, to make 1 ton of fresh water the amount of coal required is—

$$\frac{2{,}240}{8.14}=275 \text{ lbs.}$$

Evaporating Into Low Pressure Valve Chest.—In this case the steam from the evaporator is discharged into the low pressure valve casing, and does work upon the low pressure piston before being condensed. There is therefore a saving over the previous arrangement, which may be calculated as follows:

In an economical triple expansion engine 17 per cent. of the total heat in the steam is turned into work, consequently if it is assumed that the power developed in each cylinder is equal, one-third of this (or 5·66 per cent.) is developed in the low pressure cylinder.

Also, as 17 per cent. of the total heat is utilized, 83 per cent. must be re-

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FIGS. 5,717 and 5,718. ***Schutte and Koerting*** spiral corrugated feed water heater. ***In construction,*** the outer tubes are expanded into the headers and the inner tubes then screwed into place; the outer joints made tight by nuts which are locked securely. Expansion and contraction of tubes, due to heating and cooling is taken up by the floating header, which is free to move. ***In operation,*** steam enters at SE, fills the entire shell, passes up through the ports P, shown on the plan view, fills the inside of the inner tubes and drains down through the inner tubes then to the common drain D, where all the condensed water passes off to the feed tank. The feed water enters at FWI, passes through the film formed by one half the tubes to the floating header, then through the other half of the tubes and out at FWO.

jected; the amount of heat entering the *l.p.* cylinder must therefore be 88.66 per cent. of the total heat. That is to say, out of the total heat entering the *l.p.* cylinder the amount utilized is

$$\frac{5.66 \times 100}{88.66} = 6.38 \text{ per cent.}$$

Had this heat been used in the same manner as the rest of the heat passing through the engine, the amount utilized would have been 17 per cent. The amount regained in the *l.p.* cylinder is therefore

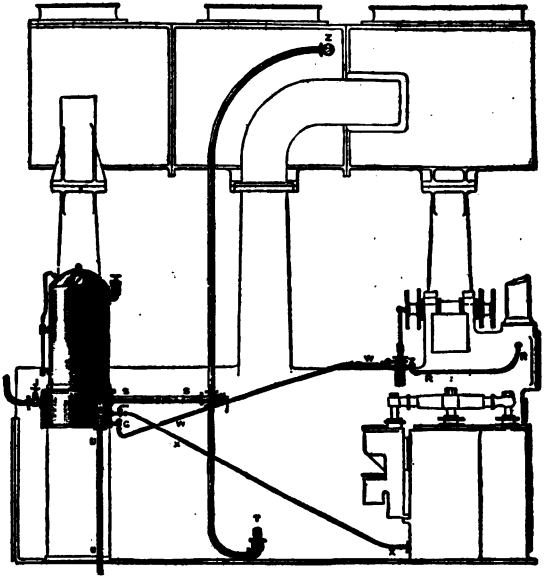
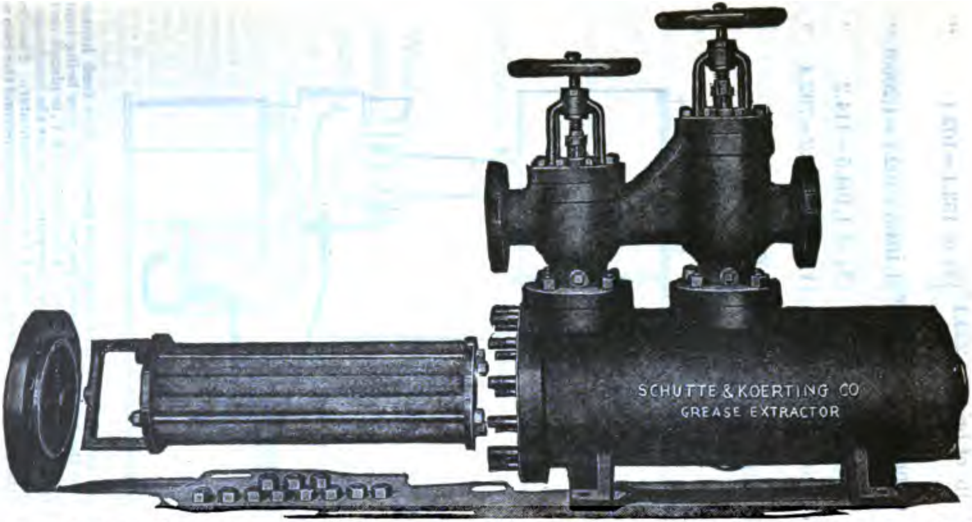


FIG. 5,719. ***Evaporator*** arranged to evaporate into ***the low pressure steam chest.*** Here it is necessary to fit a small pump V, for the supply of water to the evaporator. This water is taken from the circulating discharge, as before, by the pipe R, and enters the evaporator by the pipe W, and non-return valve G. A two way cock Y, is placed in the steam pipe S, and it is thus possible to discharge the steam from the evaporator into the *l.p.* valve casing, or into the condenser at will. A non-return valve Z, should be placed on the *l.p.* valve casing. In ordinary cases with the engine working, the steam from the evaporator would be led into the *l.p.* valve casing; but when the evaporator is used in port the steam is discharged into the condenser, thus allowing any waste of water to be made up.

$$\frac{6.38 \times 100}{17} = 37.5 \text{ per cent. or } \frac{3}{8}.$$

Now, let the pressure in the *l.p.* valve casing be 7 lbs. per square inch, the temperature corresponding to which is 233.1° Fahrenheit, and let the temperature of evaporator feed water be 80° as above, then



FIGS. 5,720 to 5,723. **Schutte and Koerting grease extractor and feed water filter; view showing filter basket removed.** Filtration is effected by means of terry linen which is wrapped around several oval cartridges comprising the filter basket. Bypass valves are so arranged that when filter basket is being removed for cleaning, the course of the feed water is directed to the boiler, without filtering. On the inlet and outlet to the filter body, suitable connections are arranged for fitting gauges, for the purpose of determining when filter should be cleaned. The terry linen can be regenerated, by boiling in a solution of soda and water. The effective area through the filter basket is 105 times the area of the pipe line, thus minimizing the number of times the basket need be removed for cleaning. Suitable connection is also made at base of filter body for blow off. Extractor is placed in the feed line, between the feed pumps and heater, or boiler. ***In operation,*** water from the feed pumps enters through valves on extractor to the filter body and travels through the filtering basket to the heater or boiler. With the increasing accumulation of foreign matter on the filtering material, the resistance indicated by the pressure gauges connected to the inlet and outlet of the filter body will increase. When the difference amounts to 20 lbs., the filter should be cleaned. An automatic water relief valve should be provided in order to prevent excessive pressure in the line between pump and extractor. The filter is put in operation by fully opening the inlet and outlet valves, while by closing the valves the water is bypassed.

Amount of heat in 1 lb. of steam at 233.1° above 80°	1,104.5	thermal units.
Amount of heat in ⅔ lb. of brine at 233.1° above 80°	⅔ of 153.1 = 102.1	"
Total heat required to make 1 lb. of pure steam, being the sum of above	1,104.5 + 102.1 = 1,206.6	"
Amount regained in *l.p.* cylinder	⅜ of 1,104.5 = 414.2	"
Net cost of making 1 lb. of pure steam is	1,206.6—414.2 = 792.4	"
Amount of steam generated per lb. of coal	$\frac{9,666}{792.4}$ = 12.19 lbs.	

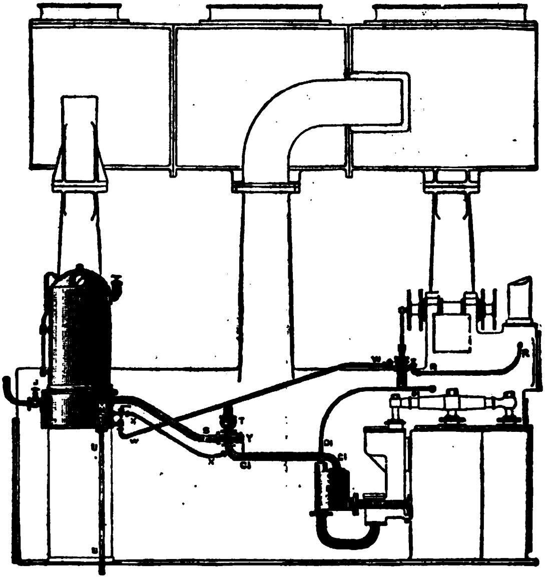


FIG. 5,724. ***Evaporator*** arranged to evaporate into ***feed water heater.*** The feed heater is shown at FH. The water from the hot well enters by the pipe A1, and after being heated flows by the pipe B1, to the main feed pump suction. A two way cock Y, is placed on the evaporator outlet pipe S, so that the steam from the evaporator may enter the condenser by the reducing valve T, or may be conducted by the pipe C1 to the feed heater. The drain from the coils may be led by the pipe X, into the pipe C1, at any point beyond the two way cock, as shown. D1 is a pipe for the escape of air and vapor from the feed heater, and is led into the hot well at any point above the usual water level. For the purpose of providing pure drinking water, part of the steam generated in the evaporator may be condensed in any fresh water condenser, and, being free from grease, it is very suitable for this purpose.

Consequently, to make 1 ton of fresh water, the amount of coal required with this arrangement is—

$$\frac{2,240}{12.19}=183.7 \text{ lbs.}$$

Evaporating Into Feed Water Heater.—In this case the steam pressure in the evaporator is about 1 lb. above the atmosphere, and as the steam is entirely condensed among the feed water, and is thus pumped into the boilers, the only actual expenditure of heat is that caused by brining.

Let the steam pressure in the evaporator be 1 lb., the temperature corresponding to which is 216.3° Fahr., and let the temperature of evaporator feed water be 80° as before, then

Heat in $\frac{2}{3}$ lb. of brine at 216.3° above 80°. } $\frac{2}{3}$ of 136.3 = 90.0 thermal units.

This being the whole expenditure of heat, the amount of steam generated per pound of coal is

$$\frac{9,666}{90.9}=106.3 \text{ lbs.}$$

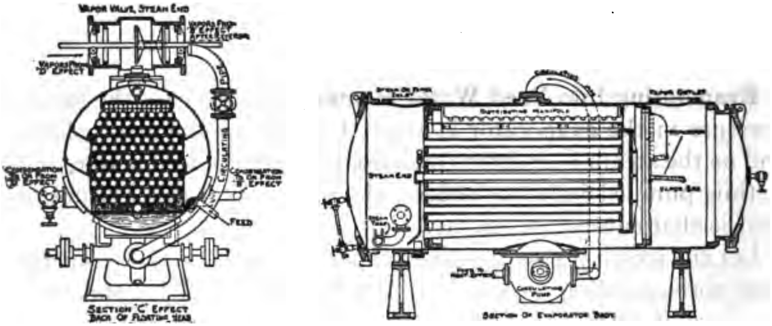
Therefore, the amount of coal required to make 1 ton of pure water is

$$\frac{2,240}{106.3}=21 \text{ lbs.}$$

412. What pumps are needed for the evaporator and distiller service?

A pump is needed for feeding the evaporator with sea water and for circulating the cooling water through the distiller.

NOTE—***Evaporators.*** The advantages of supplying marine boilers with pure water are great, and are so obvious as not to need specifying. The necessity of it was not, however, so severely felt until voyages of considerable length had been made with ships whose boilers work at pressures of 100 lbs. and upwards. The weight of water evaporated in boilers, whose working pressure is 150 lbs., is much greater in proportion to the size than was the case with those working at 75 lbs.; and the evils arising from the deposit of scale are magnified with the higher pressure and consequent higher temperature. Again, the liability to put on scale is greater, inasmuch as the losses from leakages are greater with the higher pressures. Hence, the old system of making up loss of water by a supply from the sea, although a very simple and ready one, was not by any means satisfactory, and did not remedy the evil, but rather magnified it. The Admiralty and some private ship owners tried to obviate it by providing a supply of fresh water in the double bottoms, or in tanks specially fitted for the purpose. This, however, was only half a remedy, inasmuch as the fresh water generally obtainable contained large quantities of lime and other salts which gave a hard deposit difficult to remove. Moreover this fresh water cost money, and was so much extra weight to carry which really added to its cost. Then recourse was had to the auxiliary or donkey boiler to obtain distilled water, which meant an expenditure of coal and labour in cleaning out these boilers after they had become coated. These small boilers very soon got so coated that they had to be stopped for a thorough clean-out; and during the time they were at work there was always the risk of damaging them. In spite of these difficulties it was found to be the most satisfactory way of obtaining an extra supply for the main boilers, and, consequently, improvement was made in this direction by supplying a small boiler, whose heat is obtained from either the steam direct from the main boilers or from the exhaust from one or other of the cylinders.—*Seaton.*



FIGS. 5,725 and 5,726.—Lillie evaporator, made by Wheeler Condenser Co. The operation of this evaporator differs from ordinary type in two respects: 1, evaporation from the sea water is from films caused by a mechanical showering of the sea water over the evaporating tubes; 2, the movement of the vapors or heat through the apparatus is periodically reversed. The former promotes the efficiency of the evaporating surface, and the latter, by a frequent changing of the temperatures through the *effects*, prevents incrustations to such a degree that the apparatus may be run for long periods without a material falling off in capacity. The evaporating tubes toward the steam end open through the tube plate partition, in which they are firmly expanded (without annealing). The other ends of the tubes open into a floating head or box, the front wall of which is a removable plate. The tubes are free to expand or contract independently of the shell of the effect. The tube plate, tubes and floating head may be taken from the body en masse, through the open head of the steam end after removing the bolts which hold the tube plate to the body flange. The tubes are staggered vertically, but not horizontally or diagonally, and may be cleaned by scaling irons when necessary. The heads of the effects swing on hinges, and are held closed by swing bolts. On the under side is a specially designed centrifugal circulating pump located midway between the ends of the body. Steam, or vapor from a hotter effect, enters the steam end, thence into the tubes, in which it is condensed by and causes evaporation from the sea water, which is circulated over the tubes by the circulating pump. The resulting vapors escape through a baffle plate into the "vapor end" and thence away from the effect at the top. A diaphragm which serves as a baffle separates the vapor end from the rest of the shell. At the top of this diaphragm is a hole through which the vapor enters, being deflected downward by a hood marked in the plate "Separator." Below this hood is a pan in which are placed inclined strips of copper to prevent any salt water which may be carried over into the pan splattering and thus becoming entrained. The concentration from the steam inside of the tubes flows either into the *steam end*, or into the *floating head*, depending upon the inclination given to the tubes by the motions of the ship. What flows into the floating head finds its way through the inclined pipe at the bottom into the steam end. From the steam end the condensation escapes through the steam trap to the steam end of the next coolest effect or to the surface condenser, with the exception that the one from the first, which is always the hottest effect, is taken away by itself for boiler feed, as it is more or less fouled by oil or odors contained in the steam used for evaporating. The circulation of the sea water over the tubes is a deluging shower, maintained by the centrifugal pump. The circulation is independent of ebullition, and there is no depth of sea water on the tubes, through which vapors must force their escape. The small quantity of sea water in the body is indicated. It consists of that in the body beneath the tubes plus that flowing over the tubes. ***Scaling by reversal.*** The change in temperature produced by this reversal is responsible for preventing the formation of scale in the effect by cracking off whatever scale may have been formed. If reversals be made systematically and with the frequency which experience with sea water may dictate, this evaporator may, with little trouble, be operated for many months without noticeably reducing its capacity. It is customary to reverse at intervals of about four hours when distilling sea water. The reversing operation is practically automatic, and in quadruple effects may be completed in five minutes or less.

CHAPTER 87

COOLING PONDS AND COOLING TOWERS

Where cooling water is scarce or expensive, or where it is rendered unfit for use in condensers by pollution from waste products of manufacturers, cooling ponds or cooling towers are used to cool the water so that it may be used over and over again, the small loss by evaporation being made up from an outside source.

The following examples will give an idea of the very large amount of water required where no means is provided to cool it so that it can be used again.

Example.—A 100 horse power engine runs on 30 lbs. of feed water per hour per horse power. If the cooling water for the condenser be 27 times the feed water how many gallons of cooling water are required per 10 hour day.

total feed water $=30\times100\times10=30{,}000$ lbs. per day.

$$\text{total cooling water}=\frac{30{,}000\times27}{8\frac{1}{8}}=90{,}756\text{ gallons.}$$

which at the usual city rates for water would be prohibitive, or at least the expense would largely offset the saving by condensing.

1. COOLING PONDS

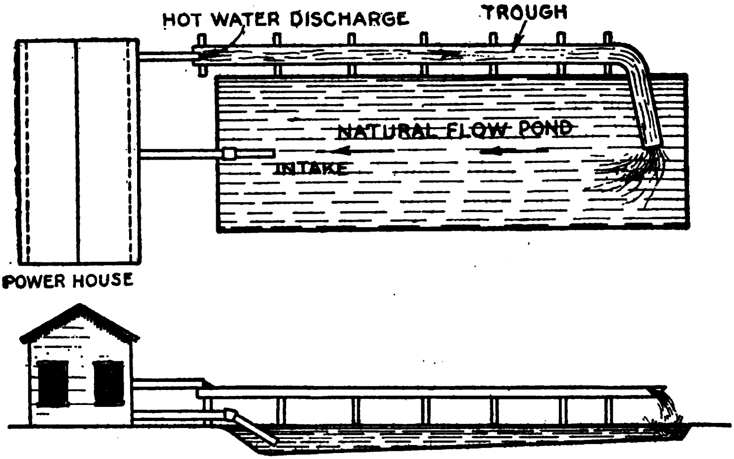
In sparsely settled districts where land is cheap, cooling ponds are used instead of cooling towers, because the considerable area required for the pond costs little, whereas the tower is relatively expensive, both in cost, operation and maintenance. Cooling ponds may be classed

1. With respect to the cooling method used, as

   a. Natural.

   b. Spray $\left\{\begin{array}{l}\text{single deck}\\ \text{double deck}\end{array}\right.$

2. With respect to circulation, as



Figs. 5,727 and 5,728.—Natural flow cooling pond suitable for long and narrow lots.

   a. Natural flow.
   b. Directed flow.

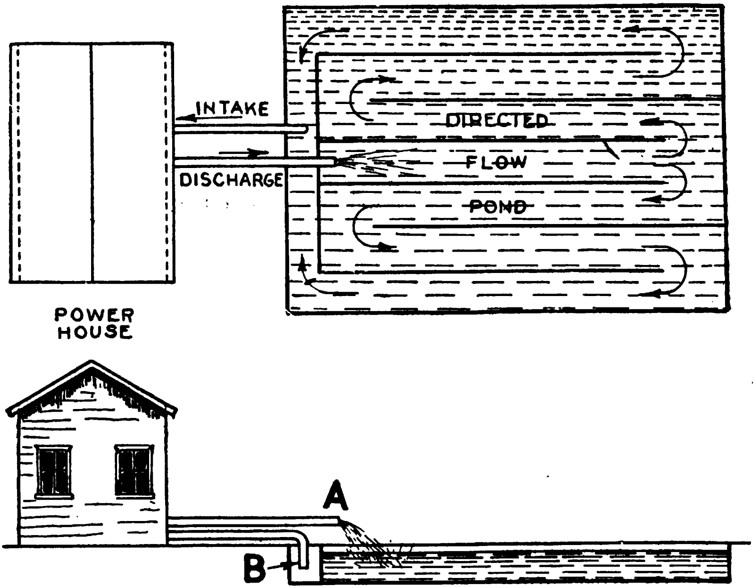
3. With respect to water capacity, as

   a. Shallow.
   b. Deep.

4. With respect to provision for preventing drift loss, as

a. Open.
b. Louvre fence.

Natural Ponds.—Where considerable pond area is available natural ponds are sometimes used, which have the advantage of requiring no spray pump. There are two arrangements, the natural flow pond, shown in figs. 5,727 and 5,728, and the directed flow, figs. 5,729 and 5,730.



FIGS. 5,729 and 5,730.—Directed flow cooling pond. The hot water enters the middle channel at **A**, and on reaching the far end divides into two currents, being directed by the baffle walls so as to traverse the pond several times before uniting at the intake point **B**.

Evidently the type to be used depends upon the ground available. When the lot is long, the natural flow pond avoids the expense of baffle walls, as required in fig. 5,729, but this is partially offset by the cost of the long trough.

The cooling effect obtained with natural cooling ponds is, as might be expected, very small, except in winter. Hence, in design, great care should be taken to have the pond large enough for severest conditions. Where the space available is not large enough, spraying could be resorted to in warm weather. The cooling is effected in three ways:

1. By radiation.

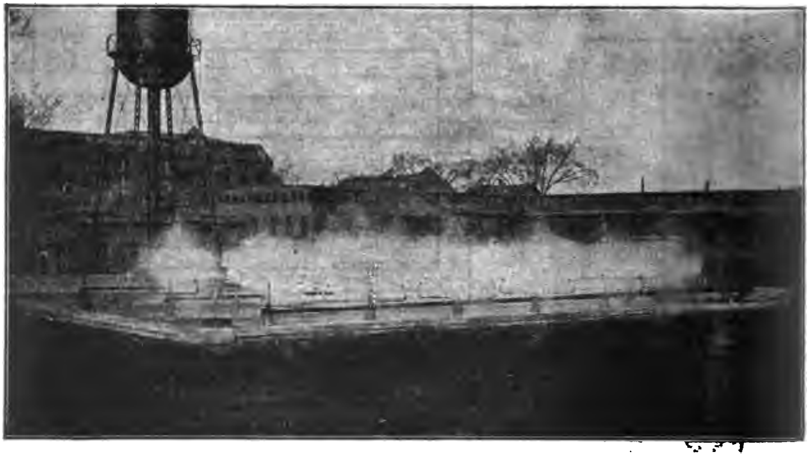


FIG. 5,731.—Spray Eng. Co. spray pond. ***In construction,*** **the pipe lines over the pond are suspended from wooden pile bents.**

2. By convection.
3. By *evaporation*.

In cold weather the first two are the most important, but in warm weather most of the cooling is done by evaporation. According to Fernald and Oriok, under the conditions prevailing in northeastern United States, it has been found that a natural cooling pond surface of 250 square feet is sufficient to cool the condensing water required for a boiler horse power (34½ lbs.) at 26 inch vacuum.

In countries where the evaporating coefficient is higher, smaller surfaces may be used (see Ruggles, *Transactions A. S. M. E.*, vol. 34, page 561).

The evaporation of one lb. of water absorbs about 1,000 *B.t.u.* The rapidity of evaporation is determined

1. By the temperature of the water, and
2. By the vapor tension in the air in immediate contact with the water.

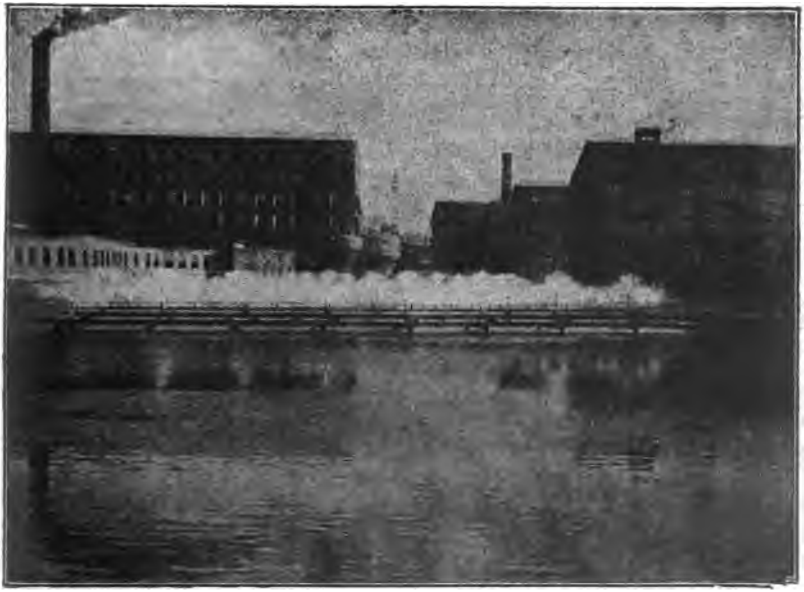


FIG. 5,732.—Spray Eng. Co. spray system erected over a natural pond in the New England States, operating at only 3 lbs. pressure during spring and fall, as sufficient cooling is obtained at this pressure, although 6 to 7 lbs. pressure is required on hot summer days.

In ordinary air, the vapor present is generally in a condition corresponding to superheated steam, that is, the air is not saturated. If saturated air be brought into contact with colder water, the cooling of the vapor will cause some of it to be precipitated out of the air. Again, if saturated air be brought into contact with warmer water, some of the latter will pass into the form of vapor.

The rise in temperature of the air from contact with hot water will greatly increase the water carrying capacity of the air, enabling a large amount of heat to be absorbed through evaporation of the water.

Spray Ponds.—Where the space available is inadequate for a natural cooling pond the spray pond is used. Here the hot water from the condenser is sprayed over a pond (or, where space is very limited, over a roof), through a multiplicity of jets. As it passes through the air in a finely divided state, its surface area is greatly increased, thus intensifying the cooling by evaporation; hence, for a given cooling capacity the size of pond is much less than that of a natural pond.

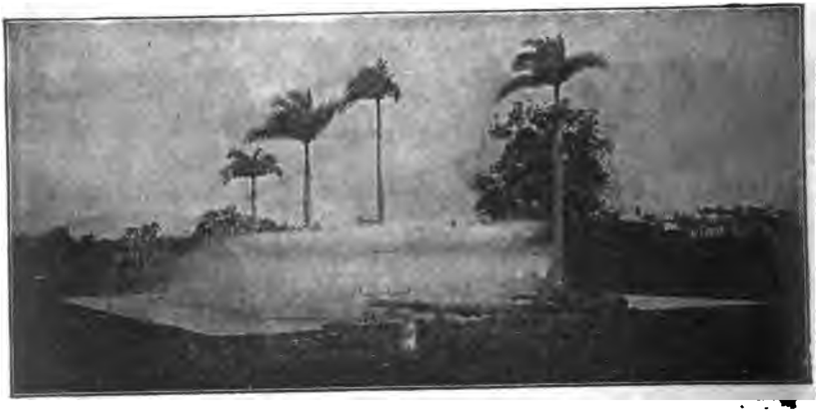


FIG. 5,733.—Spray Eng. Co. so called *double deck* spray pond of sugar mill in Cuba. The installation occupies less space because of the nozzles being arranged at two different elevations. There is more loss from *drift* in an installation of this kind than with the ordinary system, but in this case, it is not serious, as sugar mills have to waste a considerable amount of water which is allowed to overflow from the cooling pond. Where economy of water is important such ponds, especially in exposed places, should be surrounded by a louvre fence, as in fig. 5,734, to catch the spray blown past the sides by strong winds.

The sides of the ponds are sometimes extended or a lower fence provided to prevent loss of water by the spray being carried away by the air currents. The usual range of cooling varies from 20° to 40° F., depending on conditions.

About 4 sq. ft. of surface are required for a boiler horse power to condense steam at 26 ins. vacuum.

If it be desired to cool water over a large range, it can be easily accomplished by spraying more water than passes through the condenser or heating medium, by the so called double deck method shown in fig. 5,733. By this method it is possible to cool water within a few degrees of the wet bulb temperature of the surrounding air. The accompanying cut shows examples of spray ponds.

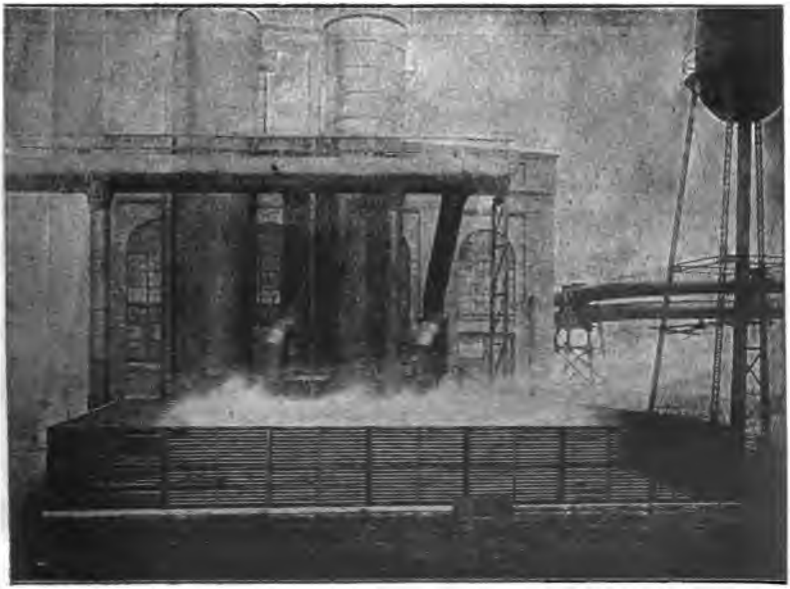


Fig. 5,734.—Spray Eng. Co. spray pond drift protected by louvre fence. This pond cools the jacket water of a gas engine plant on Chesapeake Bay. The water is sprayed at 180° and cooled down to about 100°, depending upon the time of the year, as it is not necessary to have as cool water for circulating through jackets of gas engines to obtain satisfactory results as it is to produce an economical vacuum with engines or turbines. The cut shows plainly the louvre fence, which is necessary not only to save waste but to protect the power plant which is only 20 ft. distant from the spray. Tide water is available at this plant, but was not used as it is very corrosive at high temperature.

According to the Spray Engineering Co. careful tests made by disinterested engineers, extending over a period of several weeks, show that the average amount of heat dissipated from the surface of a natural cooling pond with directed flow is 3.5 *B.t.u. per sq. ft. per hour per one degree* *difference*, and that the average heat dissipated by a spray cooling pond *is* 127 *B.t.u. per sq, ft. per hour per one degree difference* or approximately 36 times as much. This shows that a *natural* cooling pond capable of taking care of a 100 horse power plant, can be increased in capacity to take care of a 3,600 horse power plant by the addition of a spray cooling system.

With cooling ponds of any type the feed water for the boilers is not taken from the pond, but from the discharge pipe line between the condenser and the pond, thus saving the heat in that portion of the condensing water delivered back to the boilers.

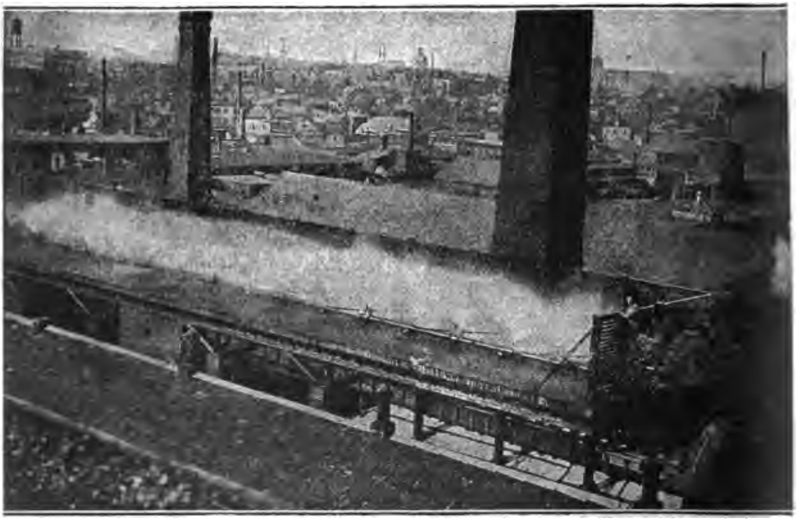


FIG. 5,735.—Spray Eng. Co. *roof type* spray pond, installed on roof of an ice plant in New England, 1,500 gallons of water per minute being cooled for use in connection with ammonia coils of 250 ton capacity of refrigerating machinery.

The ratio of condensing water to feed water should be large enough to keep the water in the pond in equilibrium for any desired vacuum, for if this ratio be such that the heating effect of the condenser is greater than the desired cooling effect of the pond, then the temperature of the pond will rise to a higher point and the vacuum will decrease a corresponding amount, thus impairing the economical operation of the engine or turbine.

With a spray cooling system when there is no breeze, an effective current of air is created in an upward direction around each nozzle, due to the movement of the spray as well as to the heating effect which the spray has on the air which comes in contact with the water, thus rapidly carrying away the warm, moist air produced, and replacing it with cool, dry air brought in from all sides over the surface of the pond. Spray cooling ponds are more efficient in extremely hot weather, when high humidity prevails than in cool weather with low humidity.

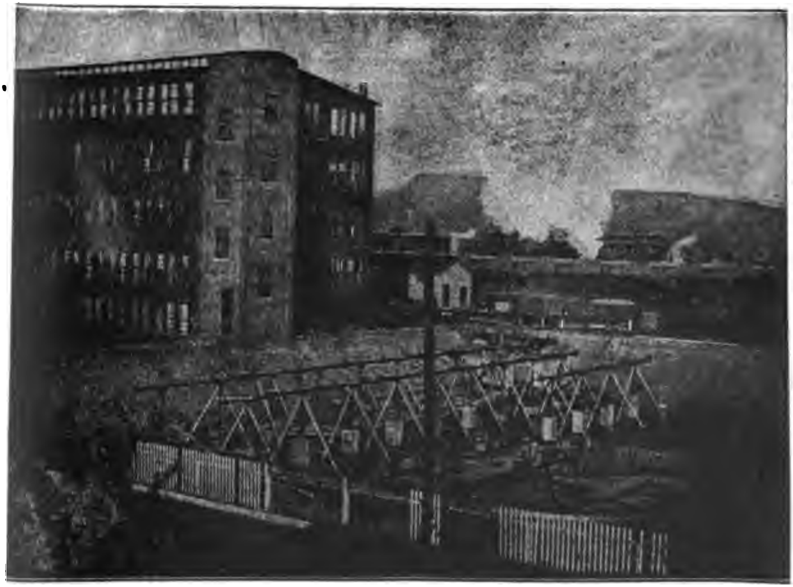


FIG. 5,736.—Spray Eng. Co. *deep* spray pond having 1,000,000 gallons capacity, 12 feet deep. The fire pumps in connection with this mill take their suction from this reservoir, and hence it serves a double purpose in cooling the condensing water and affording a large supply for fire protection.

Earthen ponds usually answer every requirement. Where provided with a grassed bank they make a neat, water tight, economical installation. Unless greater depth is needed for storage purposes, the water is rarely more than 3 feet in depth. From a cooling standpoint a pond 6 inches deep will usually give as good results as one 10 feet deep. Ponds are made deeper to provide storage for fire protection purposes.

An important feature in any spray pond is the spray arrangement over the pond or basin, and in connection with that the number and size of nozzles adopted. Many a spray system is giving poor cooling results because of the faulty engineering in connection with the pond layout.

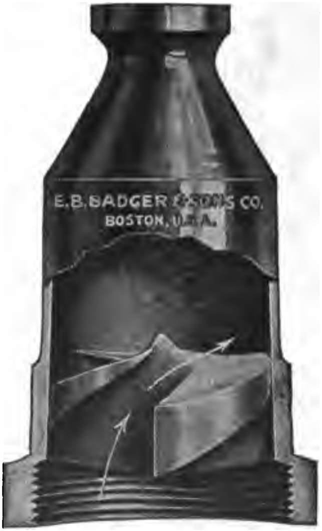


FIG. 5,737.—Badger spray nozzle showing removable turbine center for imparting the rotary motion to the liquid.

The satisfactory handling of the above features of the design and the ability to use to the best advantage existing conditions, such as old ponds, canals, rivers, and roofs is dependent on the experience and foresight of the engineers to whom the work is intrusted. Where ground space is restricted the sprays can be double decked or arranged on the roof.

Water Loss.—There is a general impression that considerable water is lost in a spray system from evaporation and drift, but careful tests have shown that the combined average loss from these causes is between 1 and 2 per cent of the amount of water sprayed, the spray particles being sufficiently heavy to settle within the pond limits.

Spray Nozzles.—An important feature of a spray pond is the spray nozzles. The object of these nozzles is to produce a fine, uniform spray at low operating pressure without clogging. They are provided with removable turbine centers having large passages.

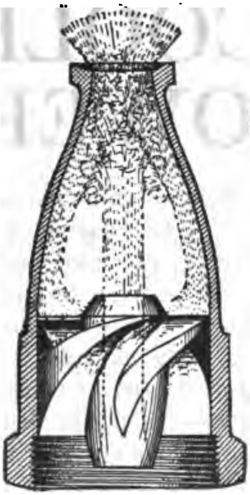


FIG. 5,738.—Spray Eng. Co. center jet nozzle. *In operation* some of the water to be sprayed passes through the outer turbinated passages and is gradually given a rapid rotating motion. The non-rotary straight central jet strikes this rotating mass of water at a point just below the orifice in the space called the mixing chamber, resulting in a mixing or blending of the rotary and non-rotary jets and compelling issuance of the water from the orifice in a fine flaring spray.

In one design, as shown in fig. 5,737, the turbine center is of such shape as to impart a rapid rotating motion to the liquid passing through it, producing a strong centrifugal action and causing the liquid to break up into a fine spray as it leaves the nozzle. In this nozzle at 5 lbs. pressure the spray issues forth in the form of an inverted cone composed of fine particles that will settle within the spray pond limit. At 7 lbs. pressure the liquid is broken up into a mist producing maximum cooling effect at low pressure.

Another type of spray nozzle, as shown in fig. 5,738, the turbine center has a central driving jet which impinges on the rotating water at the orifice, causing it to be ejected as a fine, dense uniform spray.

2. COOLING TOWERS

Where ground is extremely valuable, as in large cities, or is not available, necessitating the placing of the cooling apparatus on the roof, cooling towers are used because they occupy the least amount of space for a given cooling capacity.

A cooling tower may be defined as *an apparatus designed to remove from condensing water as much heat as can possibly be abstracted per unit of space occupied by the apparatus*. Evidently, then, the methods employed to accomplish this are not the most economical, and hence the cooling tower must be regarded as an evil necessary to meet the exigencies of the case.

Essentially, it consists of a tower or stack, from the top of which the heated circulating water is sprayed over a cellular construction of brushwood, earthenware pipes, wire mats, diaphragms or other *baffles*, designed to expose the water to the cooling influences of the atmosphere while in a film or fine rain, the process being assisted by the evaporation of part of its bulk. Counter air currents are maintained by side ventilation, natural draught (using the tower as a chimney), or by a fan blast. The cooled water collects in a tank or *sump* within the foundations, and its decrease by evaporation is made up from the public water mains or a well.

Cooling towers may be classed

1. With respect to the nature of the water baffles, as

a. Brushwood.
b. Earthenware.
c. Wire mat.
d. Wood checker work, etc.

2. With respect to ventilation, as

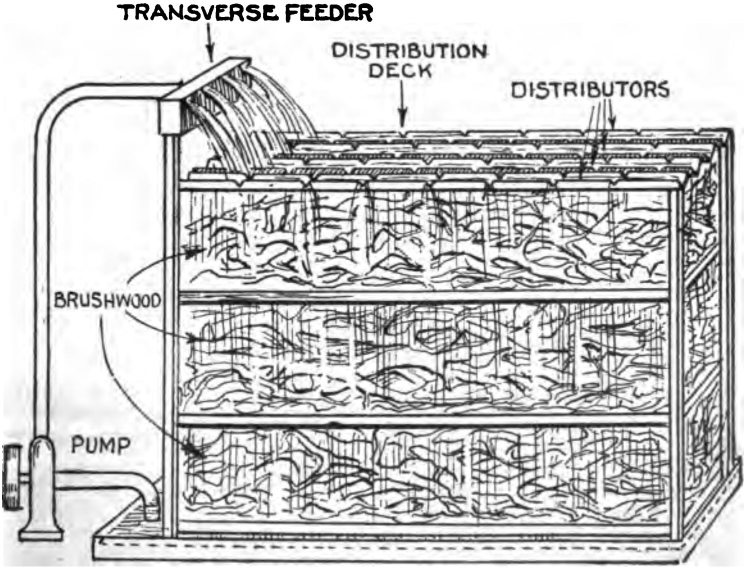


FIG. 5,739.—Open natural draught brushwood cooling tower. This is about the simplest form of tower, being of very ordinary construction. an example of this kind of tower being shown in fig 5,740.

a. Natural draught (open).
b. Induced draught (chimney).
c. Forced draught (fan).
d. Combined forced and induced draught.

Figs. 5,739 and 5,740 show an open natural draught tower of ordinary construction. In exposed windy places where the water is liable to be blown out through the sides of the tower, louvred sides are provided as shown in fig. 5,741. The natural draught tower must of necessity be of larger dimensions than the forced draught type, but the expense of fan operation is avoided.

An induced draught or chimney tower is shown in fig. 5,742, illustrating the flue or chimney above the cooling stacks, which induces a draught. The closed flue or chimney is of considerable height, erected above the portion of the tower containing the cooling surface and the water distribution system, the openings at the bottom of the tower permit the entry of the air currents and the air flow is produced by the difference in temperature existing between the top and bottom of the structure.

It is occasionally advantageous to utilize a combination tower consisting of an enclosed structure with a chimney or flue mounted over same, and having a fan as shown in fig. 5,744. A tower of this kind is larger and more expensive than the regular forced draught type, but has the advantage, that on light loads or under very favorable atmospheric conditions the fan can be shut down and large doors in the base of the tower may be opened, when a very fair degree of cooling is obtained on the induced draught principle. Generally speaking, however, the increased first cost

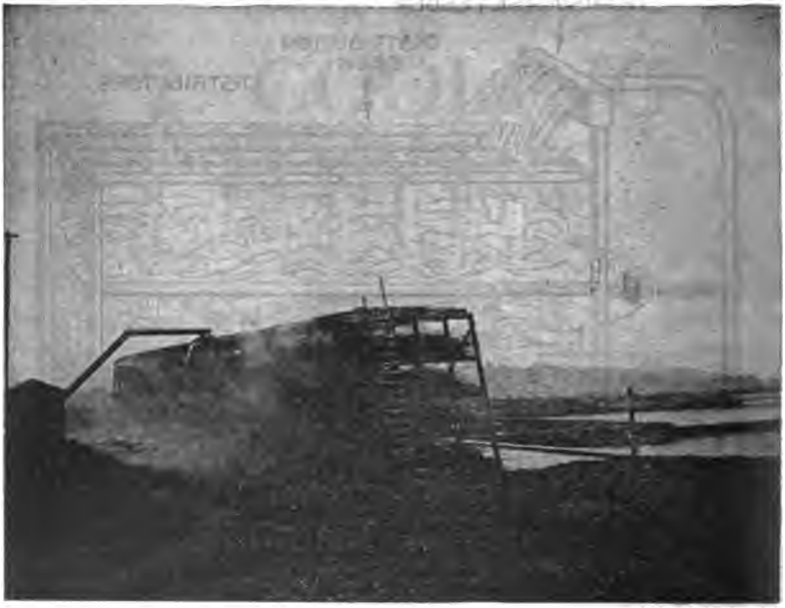


FIG. 5,740.—Open natural draught brushwood cooling tower used to increase the cooling capacity of a natural cooling pond in lieu of a sprinkler system. Such application of the cooling tower does not represent good engineering, as the same result could be accomplished by a sprinkler system at less first cost and maintenance expense.

and the increased space requirements do not warrant the adoption of this type in preference to the open, or forced draught tower.

To secure the maximum cooling capacity within a given space a forced draught tower is used, an example of which is shown in fig. 5,746. The sides of the tower are closed and the air is delivered to the interior of and forced through the tower by fans which are usually located on opposite sides as shown.

An important feature of a forced draught tower of metal construction is the provision made for painting all exposed surfaces of the housing and the

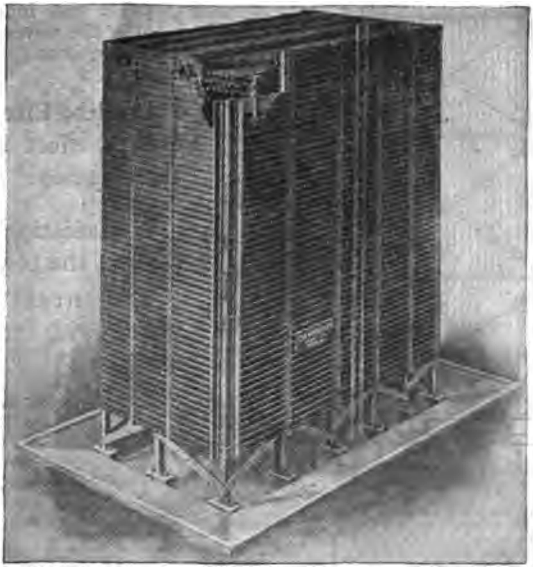


FIG. 5,741.—Wheeler louvre wall natural draught cooling tower showing arrangement of water distribution system and cooling surface. The water is delivered into one or more longitudinal feeders at the top, extending its entire length and connecting with a distribution system consisting of a multiplicity of distributors. The latter are V-shaped and the water flows from them over numerous small triangular veins to special distributing pieces attached to each under side of each distributing trough, the entire system being constructed of cypress of ample cross section. The distribution system, being open at the top may readily be cleaned while the tower is in operation. From the distributors the water falls over rows of wood of cypress wood strips, laid with alternate rows staggered so that no water can drop more than a few inches without being broken, affording an efficient spraying effect. The louvre side walls permit free passage of the air in a light breeze, yet arresting the spray in a strong wind and thereby saving water and inconvenience to adjacent property. Where towers are located close to residences, the louvres are spaced more closely on the side nearest the adjacent buildings, thereby rendering the spraying negligible. The main framework is of yellow pine waterproofed by impregnating carbolineum compound at high temperature.

supporting frame work. The inner surfaces of the housing in a well designed tower should be made accessible by removable strips inside of the tower, these being laid loosely on the horizontal racks so that a painter can start at the top of the tower and work downward, by simply removing and replacing the wood strips, checkerwork, or trays, using them as a platform on which to stand. The importance of this feature, facilitating proper maintenance at small expense, will be appreciated when it is considered that with some types it is practically impossible to paint the inner surfaces after the tower is once put in operation.

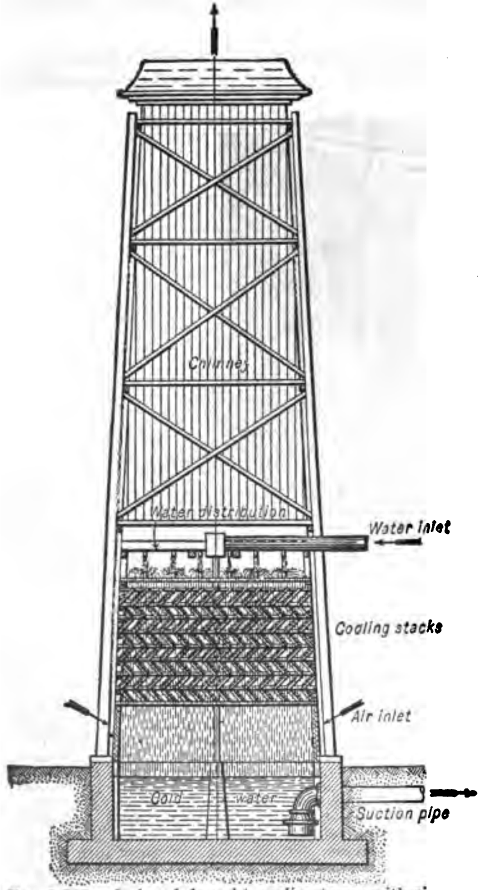


FIG. 5,742.—Induced draught cooling tower with zigzag cooling stacks.

Cooling Effect.—The cooling effect is due to three causes:

1. Radiation from the sides of the tower.
2. Contact of the water with the cooler air.
3. *Evaporation of the water*.

The first cause is practically negligible, the second may vary from $^{1}/_{5}$ to $^{1}/_{8}$ of the entire effect, and the third is the chief effect which may be easily calculated.

Example—A certain condenser requires 100 lbs. of water per minute,

which is discharged at 110°, and it is desired to cool it to 70° F. What will be the evaporation in the cooling tower?

The total heat to be abstracted from the water per minute is

$$100\times(110-70)=4{,}000\ B.t.u.$$

Now, if say 20% of the cooling effect be due to radiation and convection or contact of the water with the cooler air, then heat to be removed by evaporation is

$$4{,}000\times(100\%-20\%)=3{,}200\ B.t.u.$$

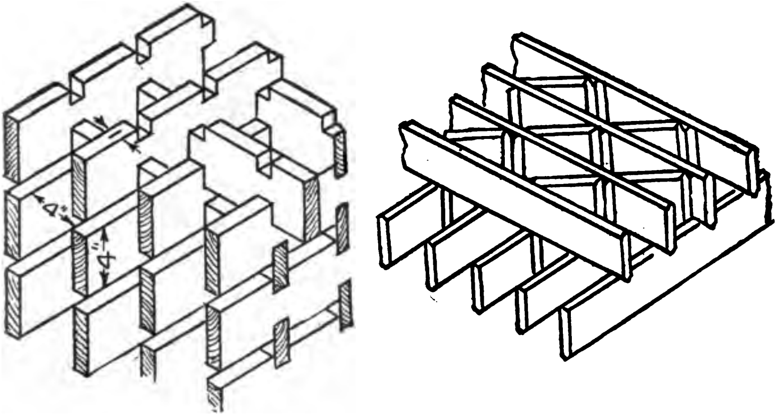


FIG. 5,743 and 5,744.—Types of wood checker work used in cooling towers.

At 110° the latent heat of evaporation is 1,030 *B.t.u.*, hence

$$\text{evaporation}=3{,}200\div1{,}030=3.1\ \text{lbs. per minute}^{*}$$

Each pound of free air absorbs 2.375 *B.t.u.* while its temperature is raised 10 degrees. Thus the temperature difference between the water and the entering air limits the heat transfer by convection. For every 1,000 *B.t.u.* of heat transferred in this

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*** NOTE.—Bearing in mind that the latent heat absorbed by the cooling water, while condensing one pound of steam in the condenser, must equal the latent heat extracted in the tower when evaporating one pound of water, the quantity of water evaporated will equal the quantity condensed, less the percentage of heat removed by convection and direct radiation. In other words, the cooling tower has to evaporate a quantity of water equaling 75 to 85 per cent. of the weight of steam (corresponding to the feed water) passing through the turbine or engine. This loss must be replaced by a fresh supply.**

manner, 422 pounds, or about 5,600 cubic feet, of air must be brought in contact with the water and warmed 10 degrees, or 2,800 cubic feet 20 degrees, etc. The same volume of air will absorb an additional and much larger quantity of heat through evaporation. Each pound of air entering the cooling tower at 72° with 70% saturation, and leaving saturated at 102° will absorb only 7.2 *B.t.u.* by its rise in temperature, but 28.7 *B.t.u.* by the water it evaporates.

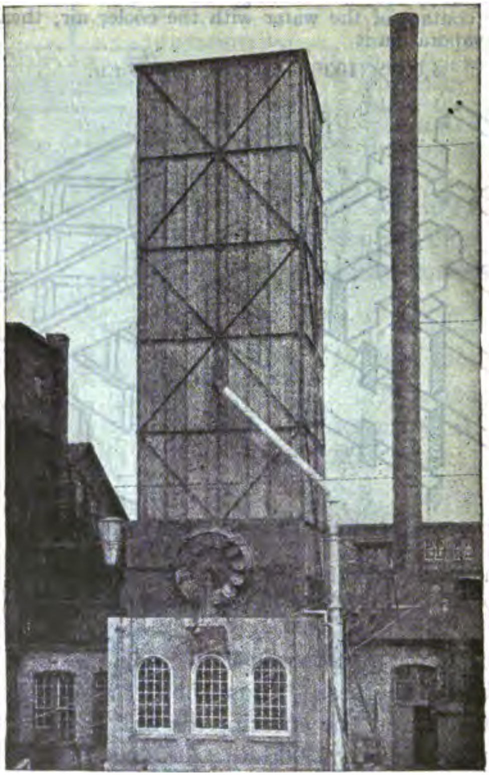


Fig. 5,745.—Wheeler combined forced and induced draught cooling tower.

As the cooling capacity of the air is limited, it is clear that an economical installation must provide means by which a large quantity of air can be brought in contact with the water spray

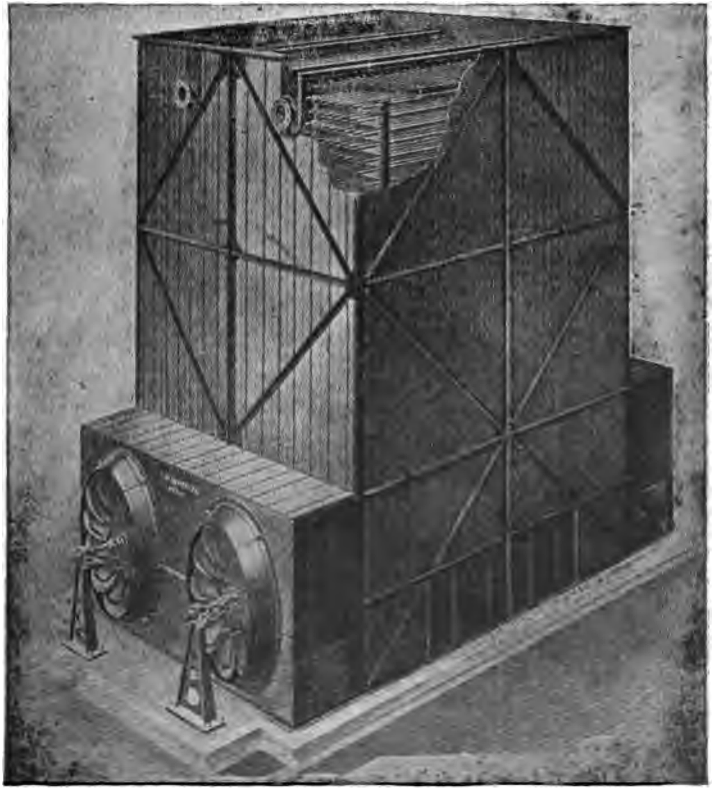


FIG. 5,746.—Wheeler forced draught cooling tower showing fans and water distributing system. ***The exterior construction,*** consisting of the supporting framework and the housing, may be of either wood or metal, the wood construction being, of course, the least expensive. In the case of the wood construction the frame work is similar to that used in the natural draught tower, while the housing consists of properly matched wood waterproofed by a carbolineum preservative compound treatment. In the case of the metal construction, the housing consists of metal sheets protected by several coats of asbestos and asphaltum applied by a special process, and the frame work is of heavy structural steel to which the housing is bolted on the inside, thereby protecting the frame work from corrosion by the water in the tower. The fans are enclosed in hoods projecting at opposite ends of the tower.

and quickly removed, after having been warmed and saturated, to give place to a fresh supply of air.

The foregoing discloses the relation of the heat to be extracted from the water and the amount of air required to absorb that heat, both directly and by evaporation.

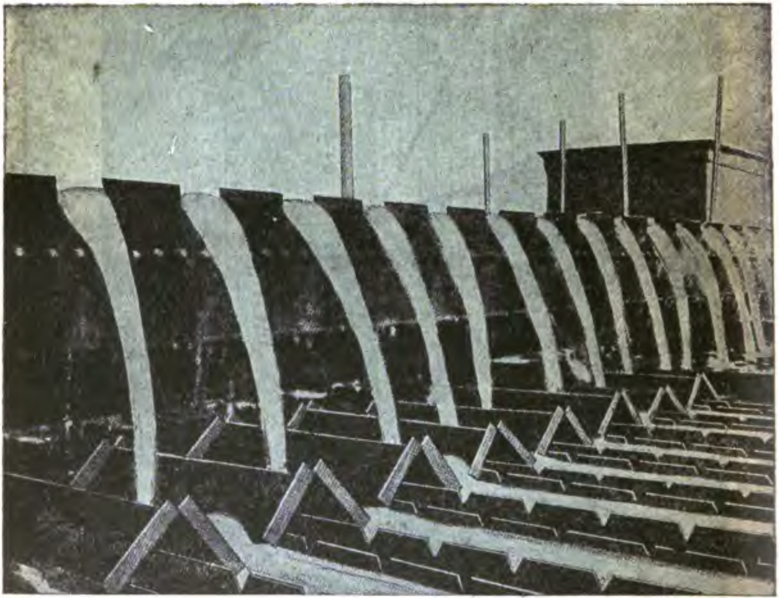


FIG. 5,747.—Burhorn cooling tower construction; *distribution deck*. At the top of the tower is provided a feeder placed in the center of the tower, and running nearly the full length of the tower on its longest dimension. At right angles to the main trough and extending at both sides of the trough are a series of distributers into which the water from the feeder discharges, as shown. The feeder consists of a steel box divided into two parts by means of a longitudinal partition. The water enters at either end through a tapped flange. One of these ends is to be plugged and will serve in cleaning out the lower compartment. A series of vertical pipes is furnished in the partition, and the water issues from these pipes, which are adjustable, so that the amount can be regulated to distribute uniformly throughout the length of the trough. The two sides of the trough are notched at intervals. Through these notches the water overflows into the distributing troughs. The feeder is made of heavy steel plate and thoroughly painted at the shop before shipment. A steel walk-way is provided running the full length of the tower along side of the feeder, giving access to the regulating pipes in the feeder, and to all portions of the tower at the top. A steel ladder is provided to give access to the walk-way from the base of the tower. The distributers are notched on the sides the full length, at intervals, and the water overflows through these notches to the trough deck below.

Air will evaporate water until saturated, and the amount of moisture absorbed depends upon its initial humidity and temperature, together with that of the water. A cooling tower, therefore, should be proportioned for average summer conditions of the atmosphere, as in the winter it will cool the water considerably more and consequently a higher vacuum will be produced in the condenser.

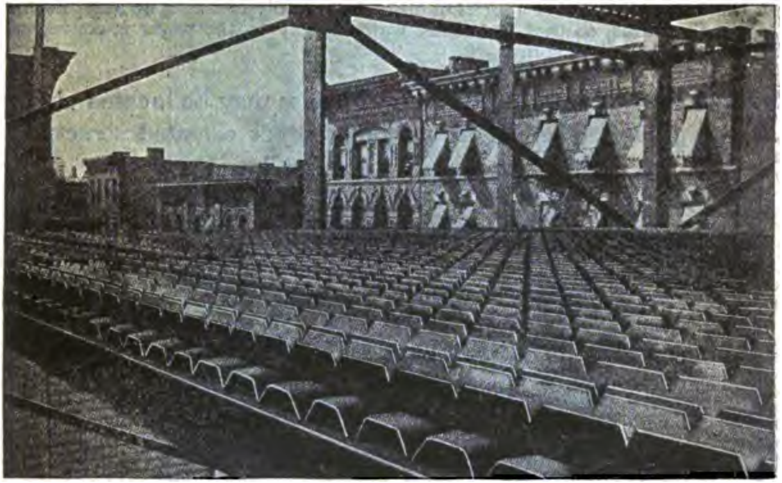
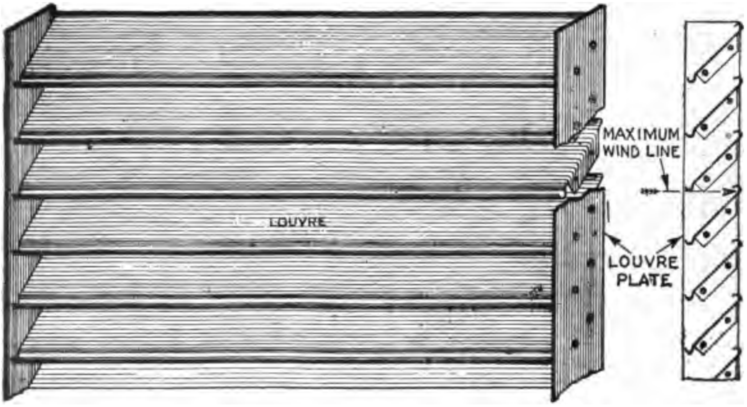


FIG. 5,748.—Burhorn cooling tower construction; *trough deck*. The trough deck system is made up of units of proper size and placed side by side so as to give the proper area to suit the capacity of the tower. Each unit consists of a series of parallel troughs notched on the two sides. These parallel troughs rest on a similar series of parallel angle pieces running at right angles and bolted together with $\frac{3}{8}$ in. bolts and double washers. The angle pieces stiffen the troughs so that they will maintain their level when full of water, and will also bear the weight of a man without deflection. The various units are bolted to channel iron beams by means of cast iron clips and through bolts, thus requiring no punching of the steel frame work. The trough deck system erected level will cause the water to seek its level in the troughs regardless of how it enters the troughs from above, and the water being level, will naturally leave the troughs through the notches throughout its entire length uniformly. The water from each notch will strike the top of the supporting angle at the center and will tend to flow down both sides of the angle pieces in equal proportion. The arrangement of troughs and angle pieces at right angles will prevent water passing directly through, but will enable a free passage of air up and around all parts of the angles and the troughs, thus exposing the water to the air under favorable conditions. The trough decks are arranged in series one directly below the other. The troughs in one deck are arranged to run at right angles to those in the deck above and below. This method will rectify the distribution of the water from deck to deck, as the tendency of the wind is to blow the water to the leeward side of the tower. Without such rectification, the water concentrates at the leeward side of the tower and, at the bottom of the tower, will splash in considerable volume. This will result in poor cooling effect and considerable loss of water by splashing out of the tower. With the trough deck system the distribution is equalized at each deck so that no matter in which direction the wind may blow, the water is always broken up into fine particles, and exposes the maximum water surface to the surrounding air. This arrangement enables the maker to guarantee efficieincy n cooling the water and also in the use of water for make up purposes.

Evaporation and convection take place on the surface of the water only; it is, therefore, essential to break up the water as thoroughly as possible during its travel from the top of the tower to the tank beneath. This process must be repeated as often as possible, so that no individual drops or streams will remain long undisturbed, as this would permit their surfaces to cool without refrigerating the inner portions. This is accomplished by allowing the water to drip over a series of obstacles, rapidly breaking up and reforming the drops, so that the entire water supply to the tower is converted into slowly falling spray.

Location of Cooling Towers.—These may be located either at the ground level or on a roof or other elevated structure, depending upon the space available and other local conditions.



Figs. 5,749 and 5,750.—Burhorn cooling tower construction; *louvre system*.

Among the advantages of the ground level installation are:

1. Simplicity of foundation and reservoir construction.
2. Shorter pipe lines, resulting in lower first and operating costs, and
3. Localization of possible spray during high winds.

With reference to cooling towers of the natural draught design, an elevated location is sometimes to be preferred because of

1. Unimpeded circulation of the air currents.

2. Utilization of otherwise unoccupied space.

The question of the pumping cost in the case of elevated towers must be given consideration. With a surface condenser

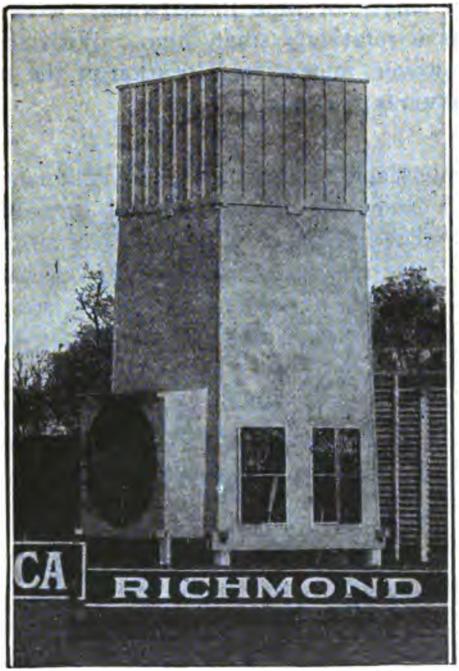


FIG. 5,751.—Bauer combined forced and induced draught tower as erected for Richmond Cold Storage Co., Richmond, Va. Capacity, 600 gallons per minute.

NOTE.—***Cooling towers.***—The condensing water coming from either steam or ammonia condensers is pumped to the top of a tower, which is usually filled with wooden or tile checker work or galvanized steel wire screens. The water in its passage down through the checker work presents a large evaporating surface to the air flowing upward through the tower, the cooling of the water being effected principally by the evaporation of a small portion of it. ***In theory,*** the action is similar to that of a humidifier. The air will leave the top of the tower 90 to 100% saturated and 5 to 15 degrees lower than the temperature of the entering water, average figures being 95% saturation and 10 degrees lower temperature. ***The limit of cooling effect*** is reached when the water has been reduced in temperature to the wet bulb temperature of the entering air at which point evaporation ceases. This is the temperature of adiabatic saturation for the given condition. Commercial installations vary considerably in the degree to which they approach this limit. Published tests indicate that the actual drop in temperature of the water passing through the tower will be approximately 30 to 50% of the maximum possible drop.—*Harding and Willard.*

the ascending and descending water columns balance each other as far as the reservoir under the tower, and the additional pumping cost is only that occasioned by the friction in the increased length of pipe lines, which, with pipe lines of ample size, is a relatively small item. With the jet type of condenser, however, an elevated location of the tower is undesirable, for obvious reasons.

CHAPTER 88

ELEVATORS

During the last fifty years the elevator has developed from a rather crude affair to a highly efficient machine. This development has been due to the gradually increasing height of buildings and the demand for high speed service. Starting with the primitive hand elevator, which was confined to the handling of freight, one feature after another was added as the necessities of the service demanded.

The great variety of service conditions has resulted in a multiplicity of elevator types, and these may be classified,

1. With respect to the motive power, as
    - *a.* Steam.
    - *b.* Hydraulic.
    - *c.* Hydro-pneumatic.
    - *d.* Electric.

2. With respect to the application of the power at the car, as
    - *a.* Plunger.
    - *b.* Drawn { drum / traction

3. With respect to the location of the power unit, as
    - *a.* Over mounted (overhead).
    - *b.* Under mounted (basement).

4. With respect to the drive, as

- *a*. Drum.
- *b*. Traction.
- *c*. Worm.
- *d*. Belt.

5. With respect to the velocity ratio between motor and car, as

- *a*. Direct drive.
- *b*. 2 : 1 reduction.
- *c*. Multi-reduction.

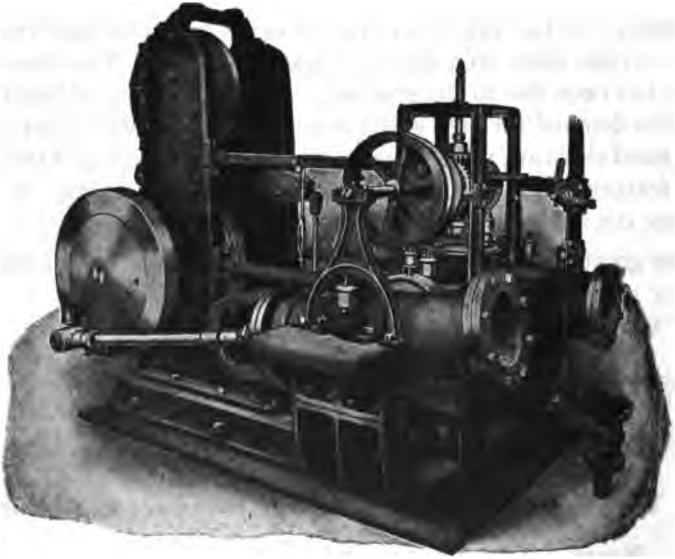


Fig. 5,752.—Reedy horizontal two cylinder oscillating steam traction elevator engine for car speeds from 5 to 800 feet per minute.

6. With respect to balancing the load, as

- *a*. Counter-balanced.
- *b*. Compensated.

7. With respect to control (electric elevators), as

- *a*. Non-reversible.
- *b*. Reversible.
- *c*. Mechanical.
- *d*. Semi-mechanical.
- *e*. Semi-magnet.
- *f*. Full magnet.
- *g*. Push button.
- *h*. One speed.
- *i*. Two speed.

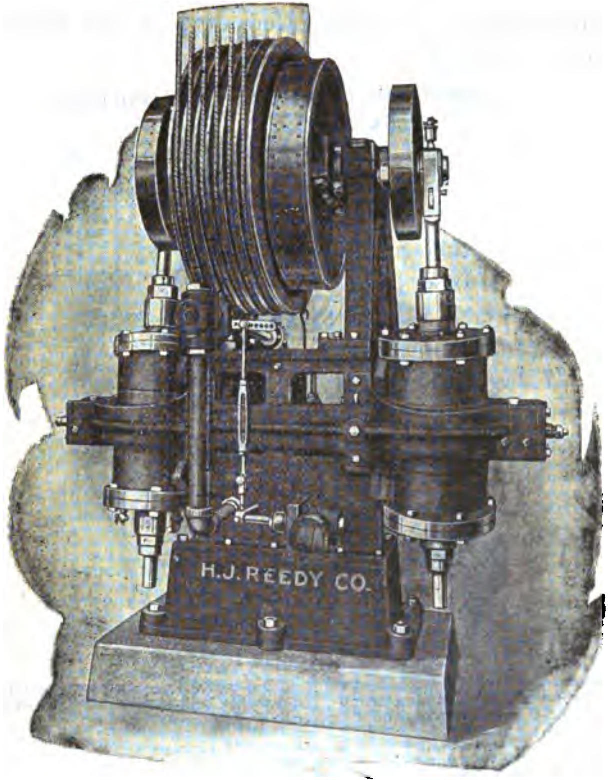


Fig. 5,753.—Reedy vertical two cylinder oscillating steam traction elevator engine.

8. With respect to service, as

- *a*. Passenger.
- *b*. Freight.

Steam Elevators.—According to Jallings, the first direct application of steam to the operation of elevators which occurred in the sixties, seems to have been, as far as economy of power was concerned, as successful as any subsequent effort. Later more compact machines were devised, but most of them were very inefficient.

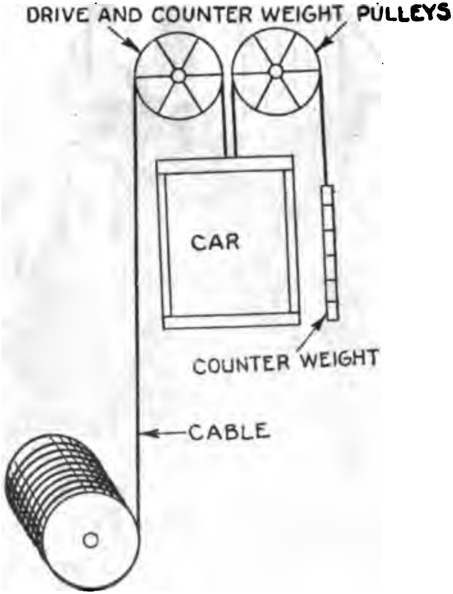
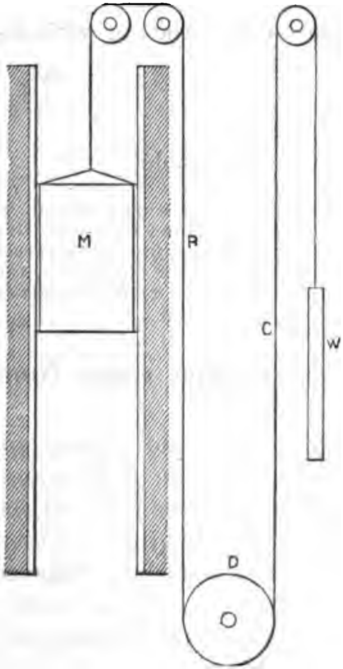


FIG. 5,754.—Drum drive or method of transmitting power from the power unit to the car by means of winding the cable on a drum. This arrangement is not well adapted to very high lifts, owing to the large size of drum necessary.

Drum Elevators.—The term "drum" applies to all elevators in which the cables leading from the car are **both** *fastened to*

NOTE.—Up to the year 1856, the only elevators propelled by power were the worm gear or spur gear types. In that year the first passenger elevator was installed in the Astor House in New York City. It was one of the two-belted, worm gear type, and its speed was only 50 feet per minute.



and *wound upon* a drum. The essential features consist of a drum operated through gearing, and to which is attached the cables which support the car, as shown in fig. 5,754.

Power, when applied to the driving gear, turning it in one direction, winds the cables upon the drum and causes the car to ascend, and when the power is reversed, the drum turns in the opposite direction, paying out the cables, and causing the car to descend.

The weight of the car is balanced by a counterweight, thus reducing the energy to be expended in operating the car. Automatic devices, to be described later, are used to insure the proper and safe control of the movements of the car.

FIG. 5,755.—Usual method of proving the counterweight. As shown the counterweight W, is joined to the drum D, instead of to the car M, the connecting cable C, being wound around the drum in the opposite direction to that in which the hoisting rope R, is wound, and anchored thereto. As the drum rotates, the two ropes or sets of rope move in opposite directions; the one set is therefore wound into the grooves on the drum left free by the unwinding of the other set. The counterbalance is generally given a weight equal to the weight of the car and its fixtures plus the weight of the average live load. When the average load is being carried by the car, the elevator is balanced, and the motor need then furnish only sufficient power to start the car and keep it moving against frictional resistances. With a live load in excess of the average, the motor will be required to furnish more power in raising the car and less power in lowering it. Thus, with a load in the car equal in weight to the maximum load. the power supplied by the motor on the up trip must be sufficient to raise the number of pounds represented by the difference between the maximum load and the average load. On the down trip, however, the maximum load may be sufficient to lower the car without requiring any power from the motor. On the other hand, if the car be empty on the down trip, the motor must provide sufficient power to raise the weight of the counterbalance which, as previously stated, is generally equal to the weight of the car and its fixtures plus the weight of the average live load. In ordinary passenger service, the average load carried by an elevator is usually less than one-half the maximum load for which the car is designed, very often not more than one-third the maximum load.

Ques. How is the counterbalance usually proportioned for drum elevators?

Ans. It is made heavy enough to balance the car with its average load.

Ques. Why?

Ans. To avoid gravity work as much as possible.

Thus with average load, very little power is required—just enough to overcome the friction of the system. It should be noted that with this arrangement, the counterweight is heavier than the car, and while power will be required to produce a downward movement of the empty car, the work done in raising the car with full load is only equal to the weight of half the load (including friction) plus the distance raised.

Ques. In construction what advantages result from placing the drum overhead?

Ans. It gives direct transmission, that is, no pulleys are required between drum and car, also the drum may be so located that one face of the drum is over the center of the car, and the other face over the counter balance, thus allowing the car cables to be fastened at one end of the drum and the counterbalance cables at the other end of the drum grooves, the car cables occupying the entire surface of the drum when the car is up, and the counterbalance cables following alongside of them, occupying the entire drum surface when the car is down.

The arrangement of placing the machine or "engine" as it is called, that is, the power unit in the top of the elveator shaft, is peculiarly adapted to the electric elevators, when the power is easily conveyed by electric conductors to the motor. The drum machine, whether over or under mounted in nearly always overbalanced as the saving in gravity work compensates for all friction and any extra first cost that might be received.

Ques. State an objection to drum elevators.

Ans. There is lack of absolute means of stopping the drum when the car or counterbalance gets to the top of the shaft.

Automatic safety devices are provided to shut off the power and apply the brake when the car is near its limit of travel. These devices are adjustable, can be removed, and may get out of order when neglected by those in charge.

Ques. For what service are drum elevators not suited, and why?

Ans. For very high lifts, because of the very large size of drum necessary to take the cables.

Traction Elevators.—This type of elevator derives its name from the fact that motion is obtained by means of the *traction*; that is to say, the friction existing between the driving pulley and the hoisting cables. In order to produce the necessary tension for this result, the hoisting cables, from one end of which is suspended the car, and at the other end, the counterweight, pass twice partially around the driving drum and only once around the idler, although frequently, before leading into the shaft, they are deflected by the idler in order to lead them plumb over the counterweight. This accounts for the necessity of having the same number of groove on each drum.

It should be noted that the grooves are straight for traction elevators and spiral for drum elevators.

The term "gearless" is sometimes ill advisedly applied to some form of traction elevator, meaning that the power is transmitted to the car without toothed gears; it is in fact, transmitted through cables and pulleys which is in fact a form of gear.

There are two forms of the so called gearless traction elevators: the 1 to 1 or direct drive type shown in fig. 5,756 and the 2 : 1 reduction type shown in fig. 5,757. A third form of traction elevator known as a multi-reduction or worm drive is shown in

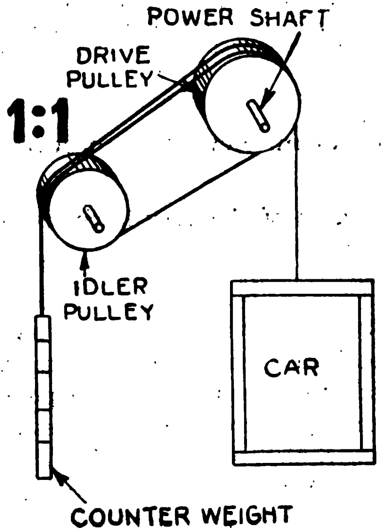


FIG. 5,756.—Direct (1:1) traction drive or method of transmitting power from the power unit to the car by means of frictional contact of the cable in passing one or more times around the drive pulley. This arrangement, since it does not employ a drum where size has to be considered, can be used for lifts of any heights, and is the prevailing type today.

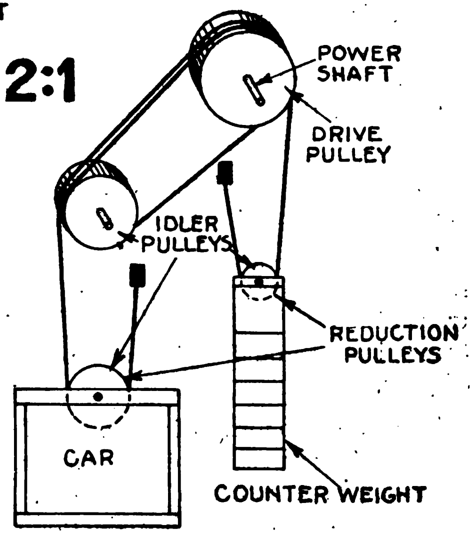


FIG. 5,757.—Geared, or 2:1 friction drive, or frictional contact transmission with reduction gear pulleys—a type used for moderate speed elevators.

fig. 5,759, the essential features of each being mentioned under the illustrations.

By comparing the three figures it is obvious that the direct drive machine (fig. 5,756) is suitable for high speed service; that the 2 : 1 reduction machine (fig. 5,757) is an adaptation of the direct drive type permitting of slower car speeds; the multi-reduction type (fig. 5,759), permitting the use of small high speed motor.

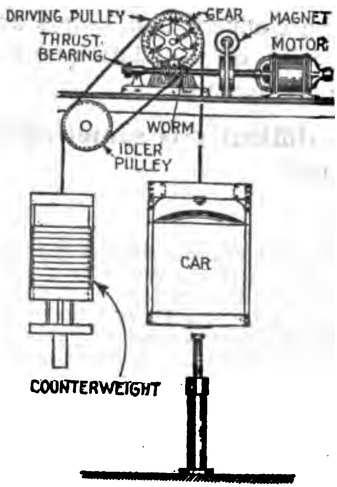


Fig. 5,759.—Diagram of an overmounted traction elevator with multi-reduction or worm drive. The traction feature is identical with fig. 5,757. Attached to the driving pulley is a gear which meshes with the worm underneath, the latter being direct connected to the motor. Clearly, the worm gives a large velocity reduction permitting the use of a high speed motor. The magnetic brake being located to act on a brake pulley attached to the fast revolving motor shaft gives considerable braking power light grip on the brake pulley. The action of the single worm gear is such as to require a thrust bearing, as later explained in detail.

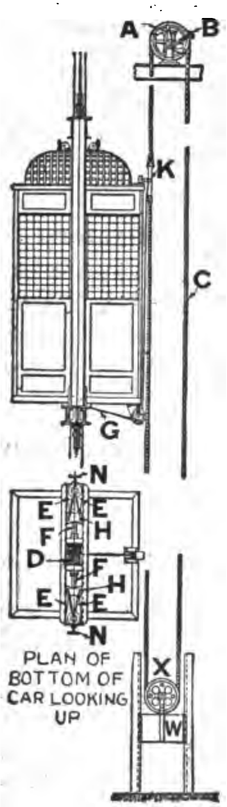


Fig. 5,758.—Elevator safety consisting of wedges forced apart by right and left hand threads turned by a drum. *This method* gives a varying pressure which gradually increases as the drum turns, and consequently produces an increasing retardation of the motion of the car. The governor A, is bolted to the beams at the head of the shaft, and is connected by the ropes C, and G, with the drum D, shown in the plan of the bottom of the car, looking upward. The rope C, passes over the governor wheel A, and around the wheel X; which latter carries a tension weight W, at the bottom of the shaft. Owing to the spring clip K, on the car, this rope under normal conditions moves with the car. If, however, the speed of the car increase above the point at which the governor is set, the arm B, of the governor flies out and grips the rope, preventing its further movement. As the car continues to descend, the spring clip K, is forced to release its frictional hold on the rope C, which latter then causes the drum D, to turn. A right and left hand nut inside of the drum D, is thus turned, forcing apart the two screw shafts FF; these acting on the wedges HH, and steel jaws EEEE, cause the latter to grip the guide rails NN, and gradually stop the car. The jaws may be released from the rails by turning the drum D, in the opposite direction to that in which the rope rotated it.

The multi-reduction type of which fig. 5,805 shows one form permits the use of a small high speed motor for operating a slow or comparatively slow car. Because of the high velocity reduction ratio of the worm gear, it is self-locking, that is to say, although the worm and gear unit permits motion to be transmitted from the worm to the gear, no load that could be put on the car would be heavy enough to cause motion to be transmitted from the gear to the worm, thus no change of loading would cause the car to descend, and consequently no car locking device is required.

Ques. State some advantages of traction elevators.

Ans. The traction elevator may be used for lifts of any height, because it does not employ a winding drum whose size has to be considered; the compact and simple arrangement of parts permits of simplicity of installation and economy of space especially when over mounted.

Ques. What difficulty is sometimes experienced with traction elevators?

Ans. Slippage.

With all traction elevators, there is the danger of slippage of the cables on the driving drum, especially if the cables become greasy. This slippage is most noticeable when the operator endeavors to stop in descending with a heavy load, with the result that on high speed cars when attempting to make a quick stop, the car sometimes slides past the landing even to the extent of one or more stories.

The fact that the traction drive is not a positive drive is a safeguard for the reason that cable strains can never increase beyond a certain limit, well within the factor of safety of the cables and fastenings. This means that the danger of the car or weight dropping, as a result of being pulled into the overhead work, and thus breaking cables or fastenings, is eliminated.

The Car.—There are two general classes of elevator car: freight and passenger; these of course vary considerably in design.

Freight elevator cars are made of wood or iron, with iron braces and fixtures; their platforms are seldom enclosed, and their design is usually of the simplest nature. Cars intended for passenger service are enclosed by a cage of wood or iron—preferably of the latter material.

In general, elevator cars should be constructed wholly of metal for safety in case of fire. Wrought iron grill work is largely employed for the sides and top of passenger cars, as it is not only fire proof but provides for ventilation and is ornamental in appearance, and at the same time substantial and of light weight.

In order to guide the car, two guide rails usually and preferably of iron are mounted vertically in the elevator shaft, and over these rails fit guide shoes that are fastened to the car. These guides are usually placed on opposite sides of the car, and in some instances at the diagonally opposite corners. In the former case the installation is said to be of the side post type, and in the latter case, of the corner post type.

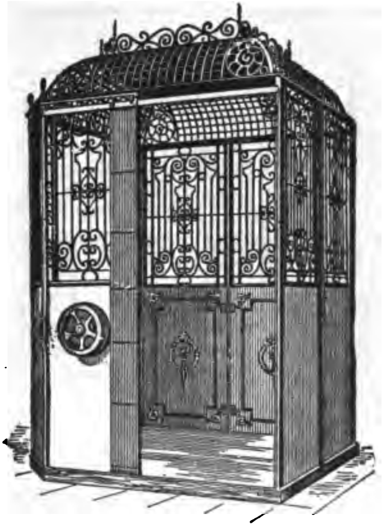


FIG. 5,760.—Typical modern passenger car. Wood or other combustible material is practically eliminated, and with the exception of the floor boards, the construction is all metal. Sheet metal is employed around the lower part and open metal grill work around the upper portion giving a well ventilated and light yet strong car.

Local conditions determine which type to adopt. The various details of car construction are shown in the accompanying cuts.

The Shaft.—The enclosure in which the elevator travels, called the shaft, and sometimes ill advisedly, the hatchway, should be enclosed with iron lattice work or grill work.

The walls should not be solid, because the solid enclosure acts as a chimney, in case of fire causing the fire to work upward from floor to floor, rendering escape by elevator impossible. A better lighted and ventilated shaft is also obtained with openwork construction of the shaft and of the doors or gates opening into it.

That portion of the shaft enclosure at each floor should be carried the full height of the opening between floor and ceiling in order to reduce the possibility of accident. When grill work is used for this portion of the enclosure, there should not be more space than one and one-half inches between the adjacent parts of the grill work to prevent objects being thrust through. Throughout the interior of the shaft there should be no projections.

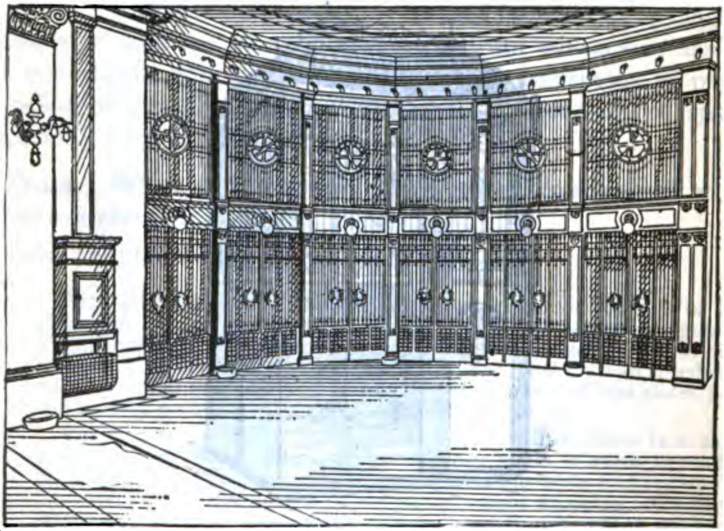


FIG. 5,761.—Semi-circular multi-shaft open iron work. With this grouping of the entrance to cars, the doors of all the cars can then readily be seen by a person entering the hall, and he can therefore ascertain at once which car to enter. This arrangement, however, should not be carried beyond the limits of a semi-circle, as the cars located in the extension are liable to be overlooked, and the efficiency of the system as a whole thus diminished.

In buildings where more than one elevator is installed, it is advisable to enclose each elevator shaft separately and have the stairways cut off from the elevator hallways. While this construction is not usually followed, the reduction in the fire risk that is otherwise present and the elimination of noises caused by the opening and closing of the elevator doors, commend it where the additional expense entailed is not prohibitive.

Hydraulic Elevators.—Water as a medium for transmitting energy has been extensively employed to operate elevators, and is still in use for that purpose today. There are two general classes of hydraulic elevators:

1. Plunger or direct drive.
2. Piston or geared.

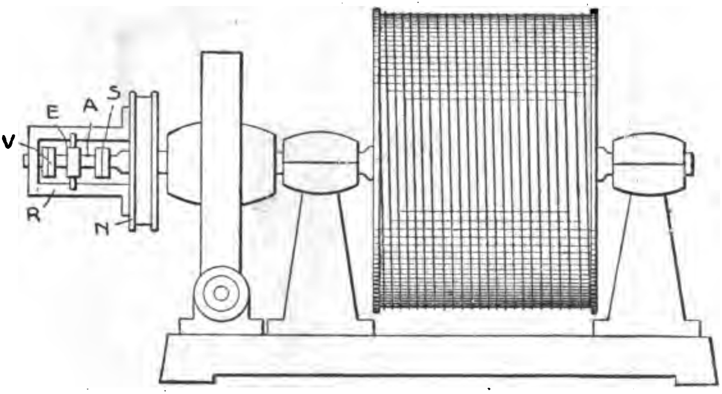


FIG. 5,762.—Machine limit stop or safety device placed on the machine to prevent over travel in case the stops on the shipper rope become inactive by the breaking of the rope. *It consists of* a threaded extension A, on the drum shaft upon which a traveling nut E, moves in fixed ratio to the movement of the car. The shipper rope pulley N, is on that portion of the drum shaft which is not threaded, and carries a bracket R, that extends over the threaded portion. Owing to two lugs on the nut E, which fit in slots in the bracket, the nut can move only parallel with the shaft when the drum rotates unless the shipper rope sheave N, moves also. On each side of the nut E, there are claws that engage with similar claws on the inner sides of the nuts V, and S, when E, and V. or E, and S, come together. Check nuts on the outer sides of the nuts V, and S, securely clamp the latter to the drum shaft, so that when the nut E, engages either with V, or S, it will, by means of the bracket S, shift the shipper rope sheave N, thus cutting off the current from the motor and applying the brake. If the nuts V, and S, be located on the threaded portion of the shaft so that contact is made between them and the nut E, when the car reaches its limits of travel, the operation of the device will stop the car automatically at both these points.

Plunger or Direct Drive Hydraulic Elevators.—The plunger elevator is supported from underneath by a steel plunger instead of being hung from above by cables, although cables are attached to the top of the car, leading over pulleys at the top

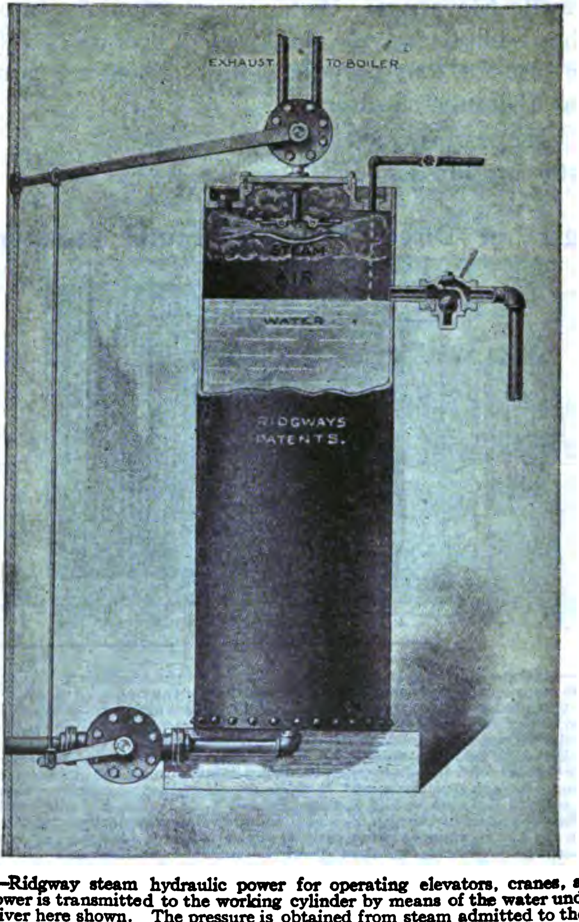
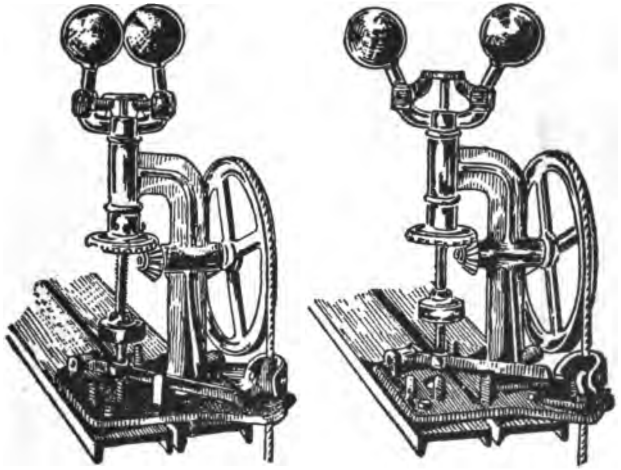


FIG. 5,763.—**Ridgway steam hydraulic power for operating elevators, cranes, and various hoists. Power is transmitted to the working cylinder by means of the water under pressure in the receiver here shown. The pressure is obtained from steam admitted to the top of the vessel and to avoid excessive condensation, a layer of air is maintained between the surface of the water and the steam. To insure the presence of a proper volume of air an inverted ball check valve is provided, as shown on the right. *In operation,* when steam or compressed air is admitted to the vessel, the ball is lifted to its seat and closes the opening to the atmosphere; when the steam or air is exhausted, the ball drops and permits any excess of water to escape and a volume of air to enter. The levers of the steam and water valves being connected by a link as shown, operate synchronously, that is, the water valve opens when the steam valve opens either for admission or exhaust and closes when the steam valve closes.**

of the shaft to counterweights. The elevator is started by the control (lever, hand rope or push button), operating a valve which permits water under pressure to enter the cylinder in which the plunger hangs, thereby forcing up the elevator. By reversing the control in the car, the water is withdrawn from the cylinder, returned to the discharge tank, the plunger gradually descends in the cylinder and the elevator comes down.



Figs. 5,764 and 5,765.—Gurney centrifugal safety governor. Fig. 5,764, governor under normal operating conditions; fig. 5,765, governor in operation through car exceeding a predetermined speed. The governor is located at the top of the shaft and directly connected to the car safety. ***When the car exceeds a predetermined speed,*** for which the centrifugal governor is adjusted, the car safety is automatically brought into action, gradually stopping the car and locking it securely to the guides by a powerful gripping pressure. Non-corrosive metal is used for the operating parts of this device, insuring its being in working condition at all times. There are no springs in the governor to assist or retard the action of the balls.

Fig. 5,766.—Reedy safety clamp for steel car guide. It is operated by a sensitive speed controller placed over the hatchway and connected by an iron cable.

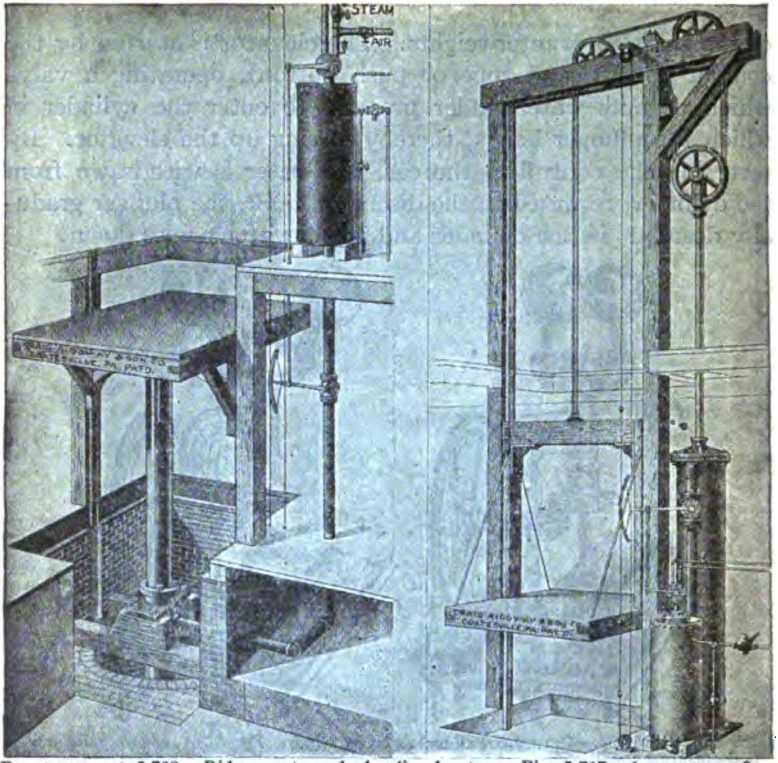


FIG. 5,767 and 5,768.—Ridgway steam hydraulic elevators. Fig. 5,767, plunger type; fig. 5,768, piston or geared type.

NOTE.—***Water under high pressure*** **(700 to 2,000 lbs. per sq. in. and upwards affords a satisfactory method of transmitting power to a distance, especially for the movement of heavy loads at small velocities, as by cranes and elevators. The system consists usually of one or more pumps capable of developing the required pressure; accumulators, which are vertical cylinders with heavily weighted plungers passing through stuffing boxes in the upper end, by which a quantity of water may be accumulated at the pressure to which the plunger is weighted; the distributing pipes, and the presses, cranes or other machinery to be operated.—*Kent.***

NOTE.—***The gross amount of energy*** **of water under pressure stored in an accumulator, measured in foot pounds, is its volume in cubic feet×its pressure in pounds per square foot. The horse power of a given quantity steadily flowing is** $H.P. = 144\,pQ/550 = .2618\,pQ$, **in which Q is the quantity flowing in cubic feet per second and** p **the pressure in pounds per square inch.** ***The useful effect*** **of a direct hydraulic plunger or ram is usually taken at 93%. The following is given as the efficiency of a ram with chain and pulley multiplying gear properly proportioned and well lubricated: gear 2 to 1, efficiency .8; 4 to 1—.76; 6 to 1—.72; 8 to 1—.67; 10 to 1—.63; 12 to 1—.59; 14 to 1—.54; 16 to 1—.5. With large sheaves, small steel pins, and wire rope for multiplying gear the efficiency, has been found as high as 66% for a multiplication of 20 to 1.—*Kent.***

PLUNGER ELEVATOR CONSTRUCTION AND OPERATION

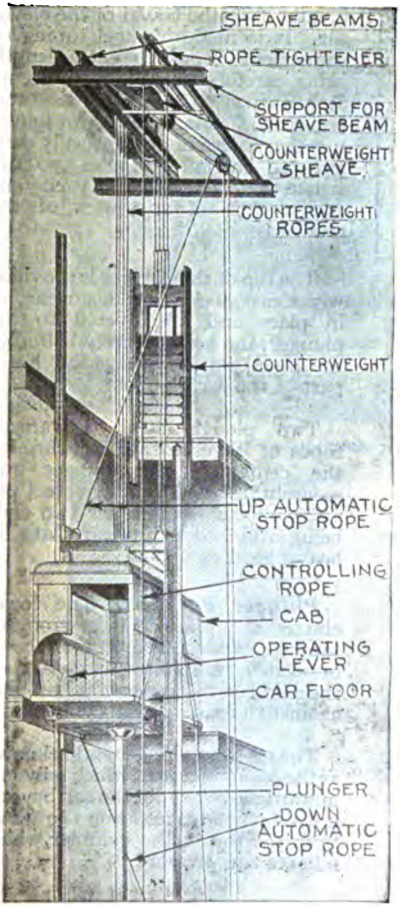


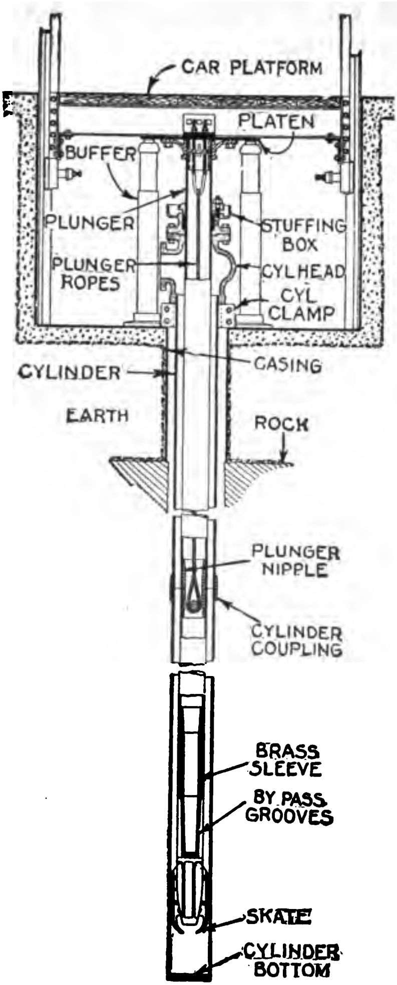
FIG. 5,769.—Standard plunger elevator, showing upper section of plunger, car shaft counterweight and control devices. Very short run elevators such as the side walk type have no counterweight and consequent overhead work.

Drilling.—A hole is drilled into the ground by driving down a casing of steel pipe and removing the earth from the inside of it. When the casing has reached solid rock a short inside sleeve is inserted to form a joint between the casing and the rock and to prevent the entrance of mud and silt into the well hole. A rotary shot drill to which a core barrel is attached is then set up inside the casing and the drilling of the rock is begun and carried down to the required depth by bringing cores of rock to the surface as they are broken off in the hole filling the core barrel.

Cylinder.—This is made of steel tubing, of approximately twenty-foot lengths, accurately straightened, squared and threaded. Butt joints are formed at the couplings to secure true alignment, smooth interior and exact length.

The bottom of the cylinder is fitted with a heavy steel plug, welded in place. The entire length of the cylinder is coated with a preservative preparation.

The top of the cylinder is provided with a cylinder head containing the stuffing box through which the plunger passes. Here, also, the connection is made to receive and discharge the water that acts upon the plunger.



Plunger.—The plunger consists of a hollow shaft, closed at the bottom, its entire length, like that of the cylinder, being also slightly greater than the travel of the elevator. It is made of steel tubing of convenient lengths, each length being carefully straightened, accurately turned to a uniform size and polished. These sections are joined together internally by specially constructed threaded nipples, so designed that the strength of each joint equals that of any part of the plunger.

The top of the plunger is provided with a cast steel flanged head, shrunk in place and hot riveted to the plunger, the head securely bolted to the steel plate forming the lower part of the car platform.

Two plough steel, galvanized ropes of large size are run through the center of the plunger and securely fastened around a steel pin at the bottom, the other two ends being attached to the car plate by heavy steel eye bolts.

Plunger By Pass.—The lower end of the plunger is a grooved, tapered casting, fitted with shoes, or skates, which act as guides for the plunger to prevent it rubbing against the walls of the cylinder.

The grooved plunger end is known as the *plunger by pass*, which prevents upward movement of the car beyond a fixed point by releasing the water from the top of the cylinder which relieves the pressure.

Fig. 5,770.—Sectional view of Standard plunger elevator showing bottom of shaft, plunger, casing, etc.

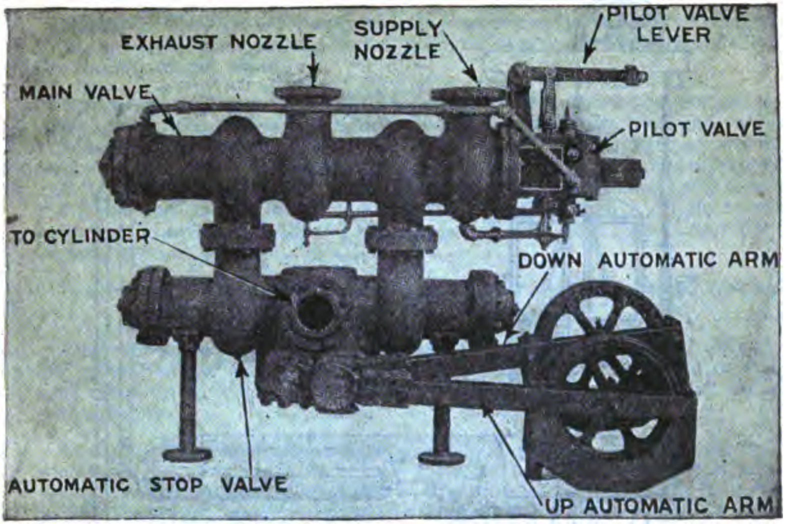


Fig. 5,771.—Standard plunger elevator "*valve*."

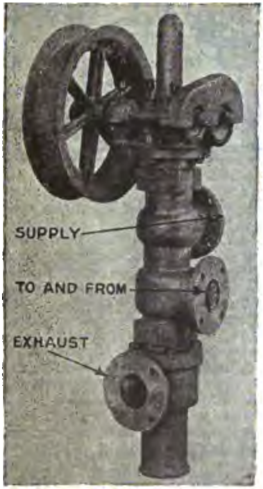


Fig. 5,772.—Standard plunger elevator three way balanced rack and pinion valve for rope controlled car. The pilot and automatic valves are omitted. *In operation,* the valve is moved directly by means of a hand rope passing through the car. Limit buttons are attached to the rope at the two limits. When the elevator engages the button, the continued movement of the car slowly closes the valve, causing the car to stop automatically and accurately at the terminal landing. The internal plunger ropes are dispensed with in short run elevators of this type. The lower end of the plunger is provided with a wing plug, instead of the more elaborate, grooved plunger end previously mentioned, but the action is exactly the same.

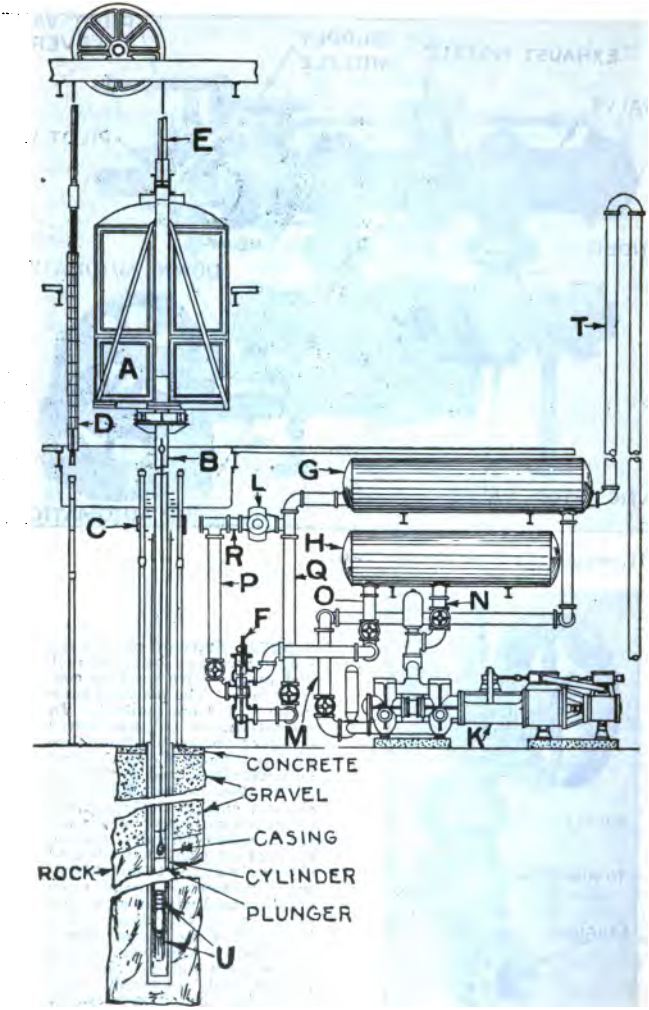


FIG. 5,773.—Arrangement of parts in a plunger elevator system. ***The parts are:*** A, elevator car; B, plunger; C, cylinder; D, counterweights; E, counterweight cables; F, valve;

Counter Weight.—The compensating counterweight ropes are attached to the car cross head, passing over a grooved sheave of large diameter to the counter weight frame.

Operation.—The car is raised by a column of water under pressure acting upon the plunger, and is lowered by gravity. The cylinder head and valve are connected by a single pipe known as the *to and from* pipe, through which all water passes to and from the cylinder, a valve controlling the direction and flow. When water is forced into the cylinder, the pressure acts upon the lower end of the plunger causing it to move upward. Ample space between the cylinder walls and the plunger allows a free flow of water in either direction.

If the flow of water be shut off, the elevator stops, the plunger resting upon a column of water.

When the valve is opened to the exhaust, the elevator descends by gravity and cannot fall or attain undue speed inasmuch as the water can escape from the cylinder only as fast as it is driven through a comparatively small port opening.

Compensating Ropes.—The ropes connecting the car and the counterweight are not for the purpose of supporting the car at all, but are part of a variable counter-weight. When the plunger is entirely immersed, it has a decided buoyancy which decreases as the plunger rises.

There must be a certain definite compensation for this loss of buoyancy caused by the ascending car, and these ropes with the counterweight are so arranged that as the buoyancy decreases, the counter-weight increases, thus insuring a uniform lifting capacity throughout the entire run. On the downward travel the compensation takes place in the reverse order.

The car and the plunger, being slightly heavier than the counter-weight, allow the elevator to descend by gravity. This difference in weight is

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FIG. 5,773.—*Text continued.*

G, discharge tank; H, pressure tank; K, pump; O, supply piping; P, "to and from" piping; Q, exhaust piping; T, back pressure loop; U, plunger bottom. ***In operation,*** the pressure tank is filled two-thirds with water, and air of the desired pressure is pumped into the remaining third, to prepare the system for operation. When the car operator throws the lever so that the elevator may ascend, the supply ports of the main valve are opened and the compressed air forces the water out of the pressure tank, through the supply piping, the valves and into the elevator cylinder. The volume of air in the pressure tank thus expands and its pressure is reduced. A pipe leading from the pressure tank to a regulator on the steam supply of the pump automatically starts the pump when this pressure begins to drop. The pump thereupon takes water from the discharge tank and delivers it into the pressure tank from which it may continue to flow into the elevator cylinder until the car operator shuts it off with his lever or the automatic stop valve does it for him at the terminal landing. When the operating valve is closed, stopping the flow of water from the pressure tank, the pump delivers water until the tank is again two-thirds full, when the automatic regulator stops the pump's operation. When the main operating valve is opened to allow the elevator to descend, the water from the cylinder is returned through the exhaust side of the valve to the discharge tank, and the pump remains inoperative. The pump operates only for the up travel of the elevator or approximately half the time.

determined by calculation in order to secure the maximum efficiency in operation.

Pilot Valve Control.—Smoothness of operation and freedom from jerks when starting, stopping and running, is secured by means of a pilot controlled self-centering balanced valve.

The ***valve***, as it is commonly termed, is really four valves in one; the pilot valve, governing the main valve, which governs the elevator, and the up and down automatic valves, which act automatically and independently at the two limits of travel to stop the car.

Ques. How is the elevator started?

Ans. The pilot valve is moved initially by means of the operating rope which is connected to the lever operating device in the car. The main valve

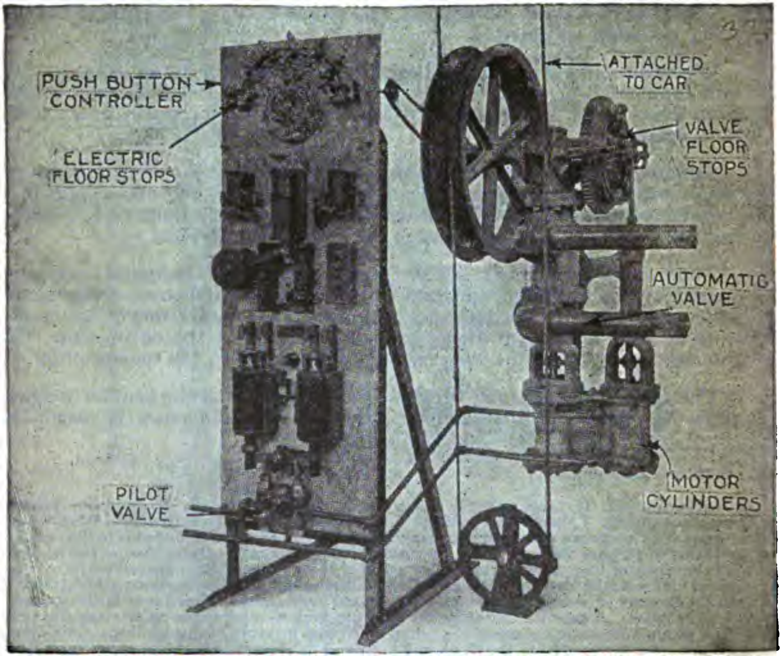


FIG. 5,774.—Standard plunger elevator three way balanced rack and pinion **valve for rope** controlled car. The pilot and automatic valves are omitted. ***In operation,* the valve is moved directly by means of a hand rope passing through the car. Limit buttons are attached to the rope at the two limits. When the elevator engages the button, the continued movement of the car slowly closes the valve, causing the car to stop automatically and accurately at the terminal landing. The internal plunger ropes are dispensed with in short run elevators of this type. The lower end of the plunger is provided with a wing plug, instead of the more elaborate, grooved plunger end, but the action is the same.**

responds to the movement of the pilot valve and moves at a fixed speed by means of water pressure.

Ques. How is the speed of the car controlled?

Ans. By controlling the extent of the valve movement.

The main valve moves correspondingly to the car lever—if the lever be moved slightly, the main valve is likewise moved slightly and the speed of the car is regulated accordingly. In this way the operator may regulate the speed of the car, but the smooth start or stop is regulated automatically.

Automatic Stop Valves—These valves cause the car to stop at the upper or lower limit automatically and are entirely independent of the main valve. As the car approaches the limit, the automatic valve gradually and positively closes, bringing the car to an easy and accurate stop, even if the main valve be left wide open. This important result is accomplished

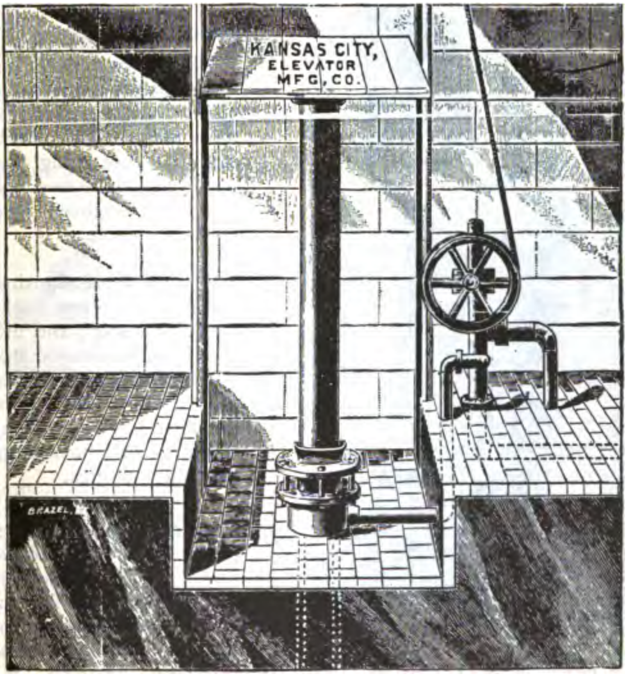

KANSAS CITY, ELEVATOR MFG. CO.
BRAZEL

FIG. 5,775.—Kansas City side walk type plunger elevator with rope operated rack and pinion valve control.

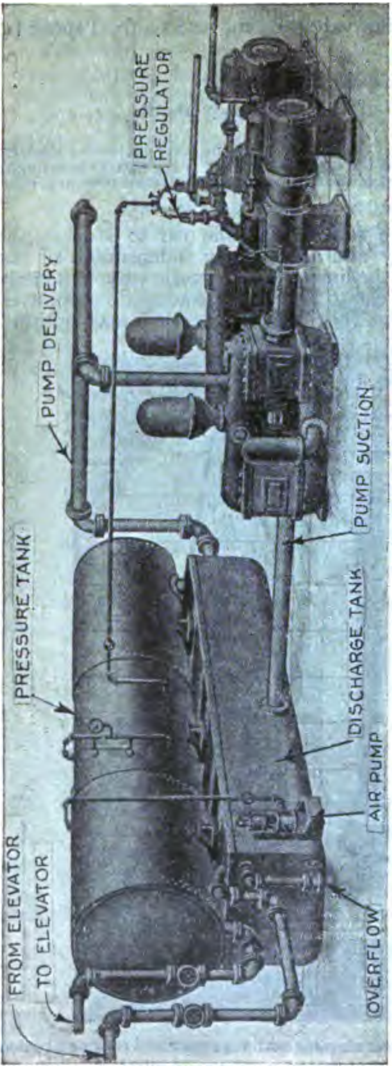


Fig. 5,776.—Standard plunger elevator pumping plant.

by means of a running rope device, the rope being called the automatic *stop rope*

The running rope device is simply a rope which is fastened to the car, passing over two sheaves at top and bottom of the well room. The lower sheave is attached to the automatic valve lever which is weighted. As the rope moves or runs with the car, it is called the running rope.

The rope slants from the car to the valve sheave, with the result that as the car approaches either limit the slant becomes more acute. The effect is the same as shortening the rope, which gradually and positively lifts the weighted lever and closes the valve.

Two of these slanting ropes are provided; one for the up automatic stop; the other for the down automatic stop, and no mechanism or contrivance of any kind aside from the slanting rope is required to effect the automatic stop at the terminal landings.

Motive Power.—The power required for the elevator is furnished by a pumping plant or city service. The different service requirements peculiar to each building, necessitate a specially designed pumping plant to meet individual needs.

As usually installed a pumping plant consists essentially of a pump, a pressure tank and a discharge tank. The same water is used over and over, flowing from the pressure tank to the cylinder, from the cylinder to the discharge tank, and from the discharge tank back again to the pressure tank, thus completing a cycle of operation.

The number of pumps and tanks, as well as their arrangement, depends upon the installation, whether large or small, but the method of operation is the same in every case.

The discharge tank in a typical installation is partially filled with water, and the pressure tank is filled to approximately two-thirds of its capacity. The remaining one-third contains compressed air at a fixed pressure.

When the valve is opened by the operator to raise the elevator, the compressed air forces the water from the pressure tank into the cylinder, which in turn gives the lifting force to the plunger.

A small air compressor is used to charge the system and renew the compressed air, if occasion requires. Steam or motor driven pumps are used; the type best suited to the individual requirements being chosen for each installation. The exhaust steam can be utilized for heating in installations where the pumps are steam driven. The resultant saving is a decided factor in economical building operation.

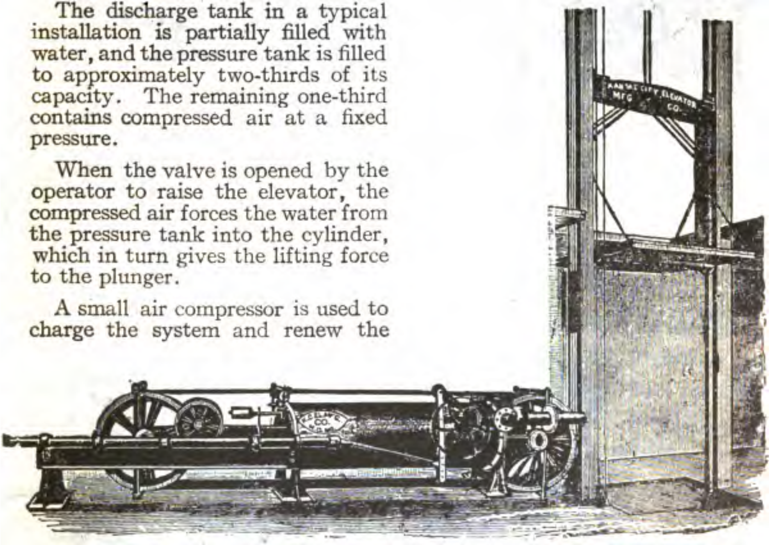

KANSAS CITY ELEVATOR MFG CO.

FIG. 5,777.—Kansas City horizontal piston or geared freight elevator.

City water pressure is often used for small installations, instead of a pumping plant, thus insuring low first cost with the utmost reliability, simplicity, and low maintenance charges.

Piston or Geared Hydraulic Elevators.—The mechanism

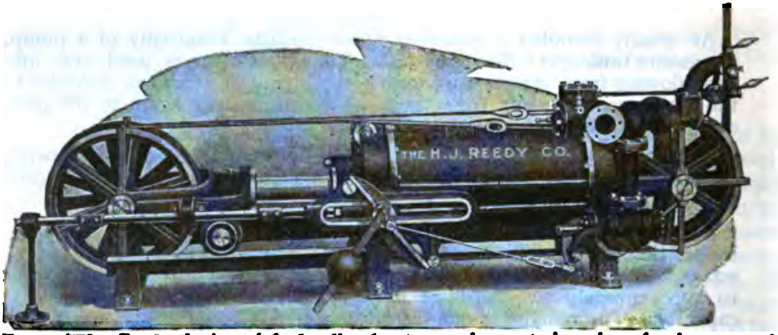


Fig. 5,778.—Reedy *horizontal* hydraulic elevator engine; exterior view showing general appearance, also the cables leading from the car, passing around the two sets of sheaves located at either end of the cylinder. One end of the cable is tied to the cylinder and the other to the elevator car. ***In operation,*** the opening of the pilot valve allows the water to open the main operating valve; this permits the water to enter the cylinder, pushing out the piston, thus separating the two sets of sheaves. In this way more cable is taken up between the sheaves and the car rises. To bring the car down, the operating valve is opened, which allows the water to escape from the cylinder, permitting the sheaves to come closer together, thus releasing enough cable for the car to reach its landing. These engines usually have either 8, 10 or 12 sheaves, half of this number being stationary and half traveling. The travel of the piston, to which the traveling sheaves are attached, is in proportion to the number of sheaves on the engine. If it have eight sheaves, then, for every foot of piston travel, the car will travel eight feet, etc. The more sheaves used on an engine, the higher the speed of the car and the less the lifting capacity of the elevator.

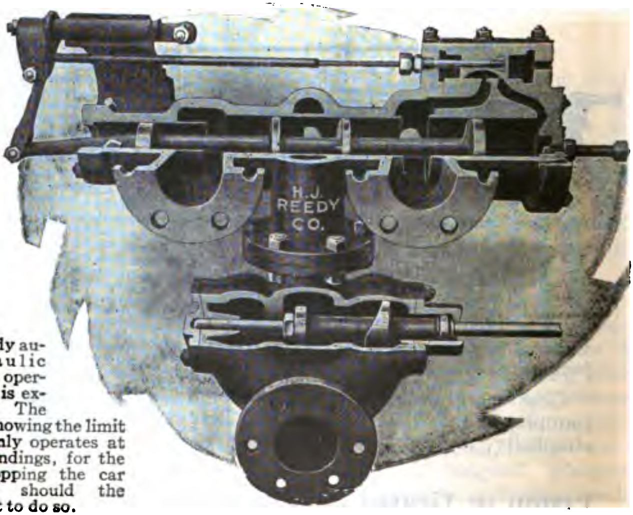


Fig. 5,779.—Reedy automatic hydraulic pilot valve, the operation of which is explained above. The lower section, showing the limit stop cut-off, only operates at the terminal landings, for the purpose of stopping the car automatically, should the operator neglect to do so.

of this class of hydraulic elevator consists of a cylinder and *piston*, the latter being connected by one or more piston rods to a cross head which carries the sheaves over which run the lifting cables from which the car is suspended.

By means of suitable valves and controlling mechanism operated from the car, water, under pressure from city main, air or gravity tank is caused to flow into and out of the cylinder, thus causing the piston to move from one end of the cylinder to the other, and back again. This motion of the piston and cross head to and fro imparts motion to the lifting cables, which pass over sheaves at the top of the elevator hatchway, and which hold the car in suspension, thus moving it up or down, according as the water flows into or out of the water cylinder. This arrangement adapts itself to geared drive, that is, the motion of the piston transmitted to the car is multiplied to a greater or less degree, according to the design, by the number of sheaves employed. Thus the speed of the car as compared with the speed

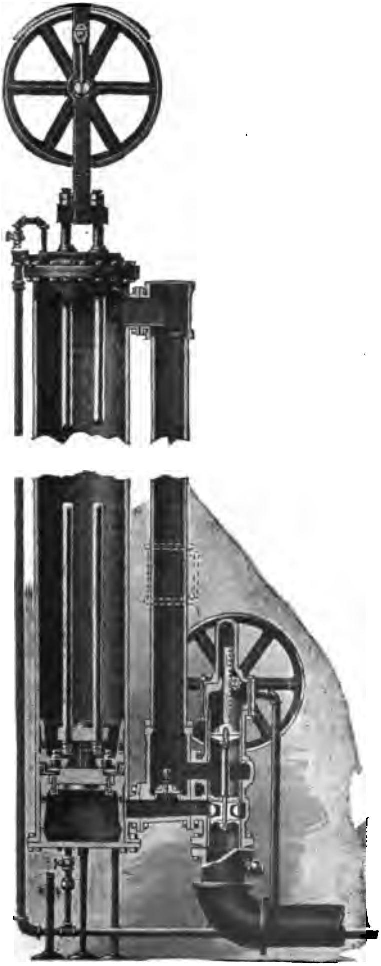


Fig. 5,780.—Reedy *vertical* hydraulic elevator engine; sectional view showing construction of piston rack and pinion valve, etc.

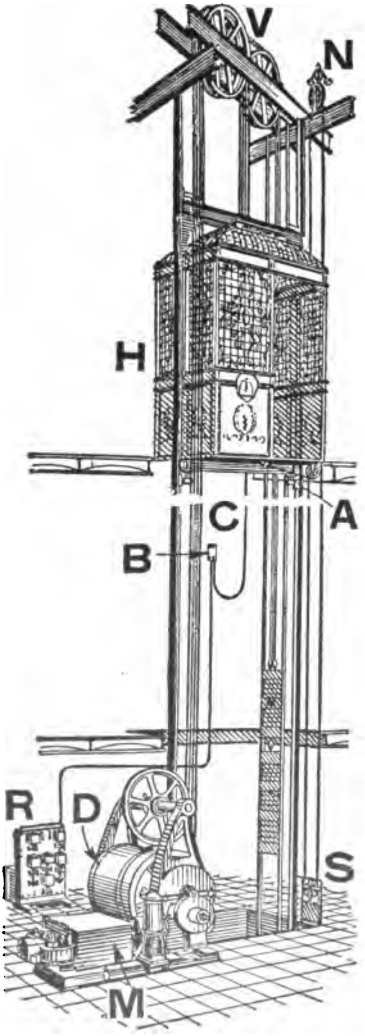


FIG. 5,781.—Undermounted full magnet drum type elevator. The hoisting drum is driven by worm gear from a motor M. The flexible conductors being shown at C, running from the car H, to a connection block B, and thence to the controller R. The overhead sheaves at V, the counterweight U, and the car safety equipment consisting of the governor N, the idler S, and the guide gripping device at A.

of the piston may be from 2 to 1 to 12 or more to 1, to meet requirements due to the nature of the service, whether freight or passenger.

The ratio of gearing also depends on the height of the building, for instance, in tall buildings it is sometimes as high as 20 to 1. There are two types of piston elevators:

1. Horizontal.
2. Vertical.

The choice depends on local conditions. Thus, if the floor space be limited, vertical cylinders are used.

Vertical cylinders are usually geared 3 and 4 to 1, though ratios of from 2 to 1 up to 6 to 1 are quite common. The general features of piston elevators are shown in the accompanying cuts.

Electric Elevators.—Electricity has been found to be a very desirable power for operating elevators, and has some inherent advantages which has caused electric elevators to grow rapidly in public favor. Ordinarily electricity is easily obtained, and the flexibility of electric equipment allows it to be installed where little room is available.

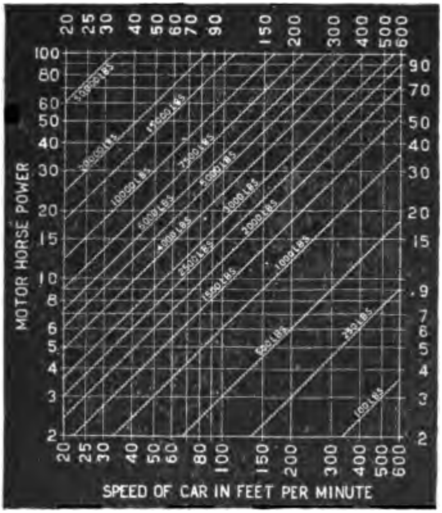


FIG. 5,732.—Elevator motor horse power diagram. Three factors determine the horse power of the motor that should be used, namely, the weight to be hoisted, the speed of travel and the efficiency of the elevator. ***In the diagram,*** the efficiency of the elevator is assumed to be 50 per cent. To determine the proper size motor to use in any case follow the diagonal line corresponding to the unbalanced load up to the point where it crosses the vertical line corresponding to the speed desired. The horizontal line at this point will indicate the horse power of motor required.

There are numerous kinds of electric elevator to meet the various conditions of service, and they may classed:

1. With respect to the current, as

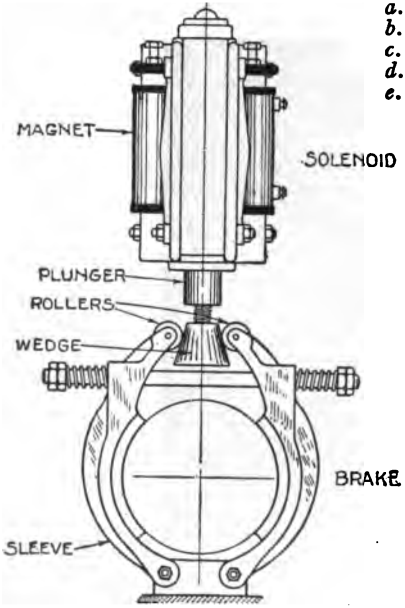
a. Direct.
b. Alternating.

2. With respect to the transmission, as

a. Drawn.
b. **Traction.**

3. With respect to the control, as

a. Non-reversible.
b. Reversible.
c. Mechanical.
d. Semi-mechanical.
e. Semi-magnet.
f. Full magnet.
g. Push button.
h. One speed.
i. Two speed.



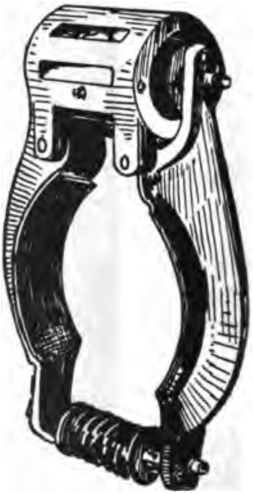


FIG. 5,783.—Typical arrangement of brake magnet having a wedge acting between rollers to release the brake.

FIG. 5,784.—Detail of Kaestner and Hecht electric brakes. ***In operation,*** the brake is mechanically closed by the spring shown at the lower end, and electrically released by the solenoid at the top.

Motors for Electric Elevators.—In estimating the horse power required for an elevator motor, the load, speed and efficiency of the system must be considered. Since it is customary to counterbalance the weight of the car and part of the load this must be taken into account, that is, only the unbalanced load is considered. Accordingly the horse power required may be obtained from the following formula:

$$\text{Horse power} = \frac{L \times S}{E \times 33{,}000}$$

in which

L = unbalanced load in pounds;
S = speed of elevator in feet per minute;
E = efficiency of the system generally taken at 50%.

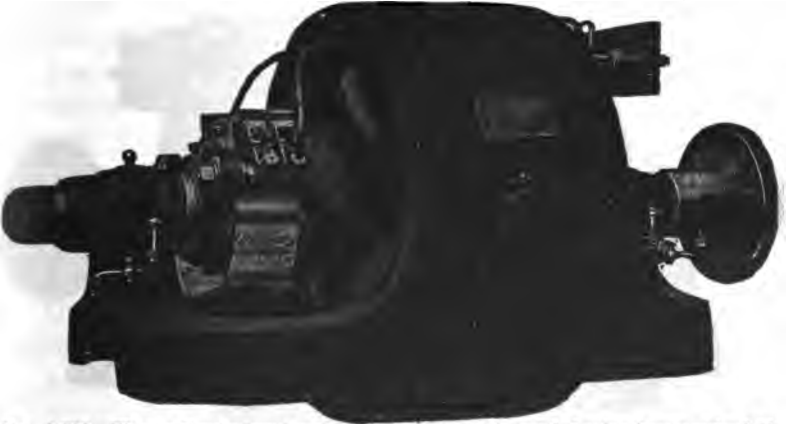


FIG. 5,785.—Warner direct current motor. It is compound wound, having heavy series field windings. The series windings are used for starting only, and are cut out of circuit as the motor attains its normal speed, in order to give the constant speed characteristic of the simple shunt motor. The standard motors up to 40 horse power are variable speed, and have a controllable range from 500 R.P.M. to 800 R.P.M. Another type of Warner direct current motor has interpoles; up to 30 horse power, the range is from 260 R.P.M. to 800 R.P.M., and 40 to 50 horse power the range is 200 R.P.M. to 600 R.P.M.

EXAMPLE.—What size motor will be required for an elevator to operate at a speed of 400 feet per minute with an unbalanced load of 2,000 lbs.?

Substituting the values in the formula,

$$\text{H. P.} = \frac{2{,}000 \times 400}{.5 \times 33{,}000} = 48$$

Ques. What kind of current is suitable for elevator motors?

Ans. Either direct or alternating, preferably direct.

Ques. Why?

Ans. Principally, because of the high starting torque of the direct current motor.

The chief difficulty experienced with alternating current motors is this lack of ability to start under heavy loads, and for this reason proportionally larger sizes must be used, the increase in horse power required being fully 33 per cent.

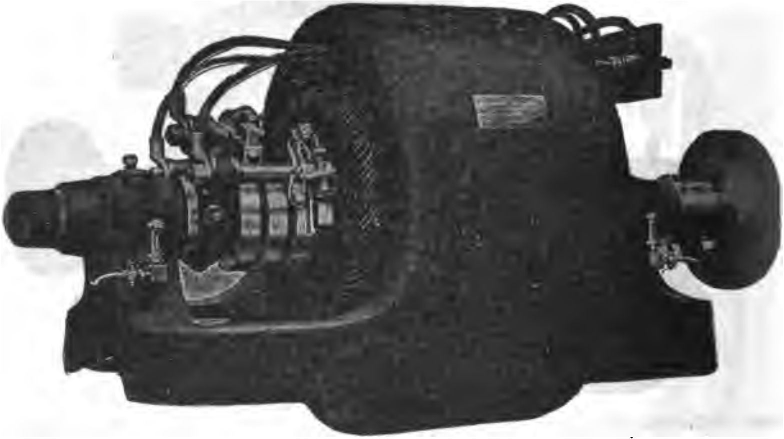


FIG. 5,786.—Warner alternating current motor. It has a standard speed of 900 R.P.M. for 60 cycle circuits, and 750 R.P.M. for 25 cycle circuits, and is of the wound rotor, slip ring type. The slip ring type gives high torque with minimum starting current, and has practically a constant speed regardless of load. An interesting feature of the Warner motors is that the alternating and direct current motors are interchangeable. Thus, an elevator built for direct current can readily be changed to alternating current in cases of a change in power.

Ques. Is the higher cost of the relatively larger size alternating current motor offset in any way?

Ans. Besides giving a heavier starting torque, it furnishes an excess of power which enables the motor to run at full speed without such noticeable fluctuations with changes in load as would be the case with a smaller motor.

Ques. What type of direct current motor gives the best control?

Ans. The adjustable speed motor having a small percentage of compound winding.

The series winding is cut out by the controller at normal speed, but is necessary in starting, insuring a smooth quick start, besides being of value in the subsequent control of the motor.

Ques. For what service is the squirrel cage induction motor suited?

Ans. It should be used only for slow and constant speed freight elevators where the impairment of the line regulation, caused by the high starting currents, is not important.

The induction motor is being used more and more for driving elevators and while admirably adapted for some classes of elevator service, it possesses certain definite limitations which should be taken into account when deciding on the type of motor to use.

Ques. What type of alternating current motor is suitable for elevators of higher speed?

Ans. Polyphase slip ring or external resistance motors.

These motors may be used on two phase or three phase circuits having a frequency of not more than 60 cycles.

Ques. Are single phase motors suitable for elevator service?

Ans. Special elevator type of repulsion induction motors, which absolutely insure reversal of the motor, can be satisfactorily employed.

Standard split phase or standard repulsion induction motors are not suitable for elevator service.

Elevator Controller.—This is a most important part of an

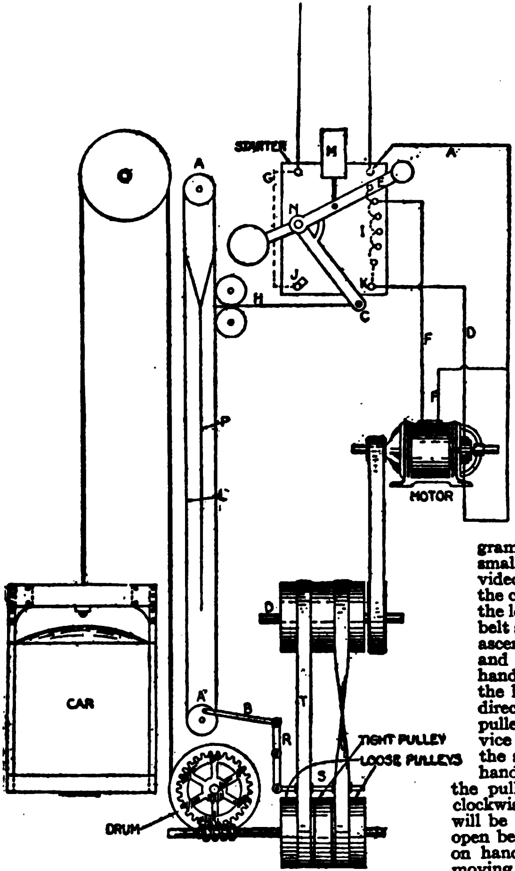
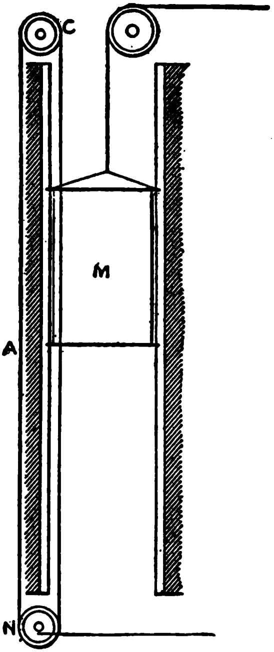


FIG. 5.787—Continuous operating non-reversible full mechanical belt driven elevator control system. As shown the elevator machine is provided with a tight center pulley and loose pulleys on the two sides. The belts are shown on the loose pulleys, one being open and the other crossed. The countershaft carries a drum wide enough to allow for the side movement of the belts when one or the other is shifted upon the tight center pulley by the belt shifter S. *To operate the elevator* a hand rope is provided which runs up the elevator shaft at one side of the car from bottom to top of building. This rope is shown in the diagram at L, and runs around two small pulleys AA′. Pulley A′ is provided with a crank pin, which moves the connecting rod B and thus rocks the lever R, and thereby moves the belt shifter S. To cause the car to ascend, hand rope L is pulled down, and to make the car descend, the hand rope is pulled up. Accordingly, the lower pulley will rotate in one direction when the hand rope is pulled to make the car go up and vice versa. Pulley A is shown in the stop position, hence, when the hand rope is pulled down for up trip, the pulley will turn in a counter-clockwise direction, and thus the belt will be moved to the right, bringing open belt into operation. Pulling up on hand rope rotates A clockwise, moving belt to left and bringing cross belt into operation, thus causing car to descend. P is a stop rope and is connected with the two sides of the hand rope as shown and if pulled when car is in operation, will bring L to position shown, stopping the car. *In operation* when the hand rope L is pulled in either direction, H, draws C to the left and contacts with J, thus current passes through starting resistance I to motor armature through D. The field circuit branches off from upper end of I and reaches field coils through F, and reaches return wire through D and thus the opposite side of the circuit. When C is pulled to left, E gradually follows by gravity and dash pot control. The elevator machine is provided with a brake, actuated by the belt shifter S, applying brake when belts are in positions shown; when belt shifter is moved in either direction, brake is released.



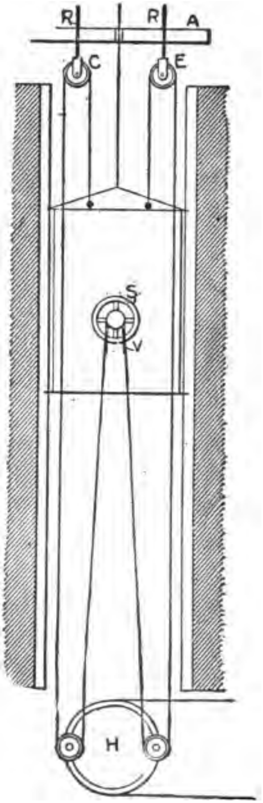


Fig. 5,788.—Mechanical control by shipper cable. ***As shown,*** an endless cable A, known as a shipper cable, is led up one side of the shaft and over a pulley C, down through the elevator car M, as shown, and around a pulley N connected to the switch or regulating apparatus at the motor. If, then, the operator in the car pull that portion of the shipper cable passing through the car, either up or down, he regulates the action of the motor and consequently of the car. For high speeds this style of control is not satisfactory.

Fig. 5,789.—Mechanical control by wheel; a method suitable for high speed cars. ***As shown,*** the ends of the shipper cables are fastened to the top of the car. The idlers C and E over which the cables pass are supplied by springs RR on a cross bar A which is fastened across the top of the shaft. A pulley H is placed at the bottom of the shaft, and a hand wheel S is used in the car for control, the shipper cable being roped around the pulleys as shown, that portion of the shipper cable near the hand wheel being replaced by a chain V which engages with a sprocket wheel mounted on the same shaft with the hand wheel. ***In operation,*** turning the control wheel to right or left causes a like movement of the pulley H, as is evident, thus transmitting the motion to the motor controller.

elevator installation, as upon its proper working depends the safe and satisfactory working of the car. It performs a number of functions, such as releasing the brake, starting, accelerating, slowing, and quickly starting the car.

The control may be classified:

1. With respect to the rotation of the motor, as
   - *a.* Non-reversible;
   - *b.* Reversible.
2. With respect to the current, as
   - *a.* Direct;
   - *b.* Alternating.
3. With respect to construction, as
   - *a.* Full mechanical;
   - *b.* Semi-mechanical;
   - *c.* Semi-magnet;
   - *d.* Full magnet.

Non-Reversible Controllers.—The simplest way in which a motor can be installed to drive an elevator, is to arrange it so as to drive a counter shaft continuously, in which case the elevator is stopped and started by throwing belts on the tight or loose pulley as in fig. 3,236.

This system may be fully classified as a continuous operating non-reversible full mechanical control system. Obviously the term non-reversible refers to the motor which always runs in one direction as distingusihed from motors which reverse their rotation to reverse the motion of the car.

The principal difference in the mechanism of a full mechanical reversible or "single belt" installation and the non-reversible system is that the tight and loose pulleys are replaced by a single tight pulley and a reversible controller provided.

The foregoing types are simply combinations of an electric motor with a belt drive transmission.

To avoid the inherent defects of belt drive, and for economy of space,

the motor and winding mechanism are direct connected which is the form in most general use.

The distinction between the various classes of controller, known as non-reversible, reversible, mechanical, semi-mechanical, semi-magnet, full magnet, and push button is illustrated in the accompanying cuts.

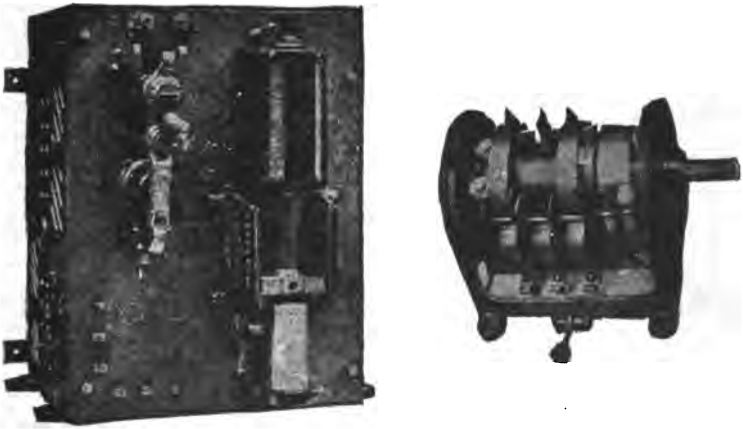


FIG. 5,790 and 5,791.—Cutler Hammer direct current reversible single speed semi-magnet controller with separate reverse switch for slow speed passenger or freight elevator. Fig. 5,790, self starting; fig. 5,791, Schureman type BR reverse switch. The controller consists of a sliding contact controller panel with main line magnetically operated clapper switch, and a separate drum reverse switch. The main clapper switch is controlled directly from the reverse switch by means of suitable auxiliary contacts, the action of the clapper switch being such that the motor circuit is always opened or closed with a snap. The main switch is so interlocked with the rheostat that the motor cannot be started or reversed until all starting resistance is in circuit, insuring smooth acceleration. The reverse switch is of the drum type designed for use with lever, wheel, or crank control, or may be operated by hand cable. The arrangement of contact is such that, although the reverse switch is of the slow break type without a centering spring, the motor circuit is opened at the clapper main switch, thereby eliminating destructive arcing on the reverse switch contacts. A mechanical connection may be made between the traveling nut of the winding drum and the reverse switch which will serve to throw the latter to the off position at either limit of travel. Limit switches may be used, however, and in many cases the use of shelf limit switches will obviate the necessity of installing the more expensive traveling nut device. Where shaft limit switches are used the hand cable is connected to the drum reverse switch only. Two single pole shaft limit switches should be installed, one at either limit of elevator travel. These can be arranged for operation by the car, or may be so installed that one switch is operated by the car and the other by the counterweight. The limit switches should be connected between the drum reverse switch and the controller panel so as to open the circuit of the main switch coil and stop the motor whenever the car arrives at the top or bottom of the shaft. With all semi-magnet controllers the mechanical brake is usually released by the operation of the hand cable. It is possible, however, to use a solenoid operated brake with these controllers by the addition of suitable contacts or relays to the controller. In connection with the hatchway limit switches a brake solenoid and slack cable switch should always be installed.

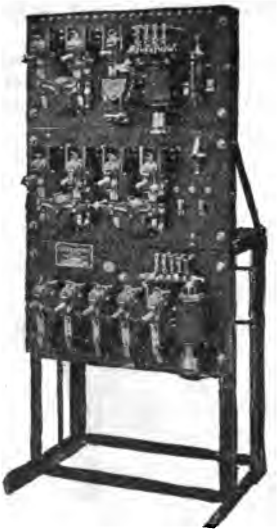


Fig. 5,792.—Cutler Hammer (Schureman type M) direct current reversible one or two speed with slow down full magnet controller for high speed passenger elevators. ***Slow down.*** This feature gives about one-quarter of the normal speed, the normal speed being for single speed equipment, the running speed, and for two speed equipment, the speed obtained with full field on the motor and all the armature resistance cut out of circuit. ***Controller panel.*** This is built in three sections in which the necessary armature resistance is mounted. The field and control resistances are mounted in a suitable frame on the back of the control panel. The field resistance has a wide range of adjustment so that the speed of the equipment can be regulated to the desired value. Suitable interlocks are supplied so that the main and reverse switches cannot be energized until all of the starting resistance is inserted in the armature circuit. Similar interlocks are supplied for giving proper sequence in the operation of the switches. ***Apparatus on controller panel.*** 1. double pole main line magnetically operated switch; 2, double pole magnetically operated direction switches; 1, single pole magnetically operated "slow down" or "dynamic brake" switch; 1, single pole "slow down" relay; 1, acceleration movement consisting of a set of crank switches operated by a solenoid and retarded by a dash pot; 1, try out switch; 2, control fuses; 1, double coil overload movement. In addition to the above, for two speed controllers there is one four step field weakening switch. ***Functions of switches.*** A double pole main line switch breaks both sides of the line and in connection with the direction switches gives four breaks in the armature circuit. The direction switches are mechanically interlocked to prevent their simultaneous operation which would cause a short circuit on the line. These switches will automatically open on abnormal drop in voltage and stop the equipment. The slow down, or dynamic brake switch inserts armature shunt resistance in the slow down position and also keeps this resistance in circuit in the off position until the motor has practically stopped, thus giving a powerful dynamic braking effect. The slow down relay handles the accelerating solenoid current, thus eliminating the arcing on the car switch contacts, which would occur in case the accelerating solenoid was handled directly from the car switch. The time of cutting out the armature resistance is adjusted by means of a needle valve in the bottom of a large vacuum dash pot. The try out switch enables the attendant to run the car directly from the control panel without the necessity of getting into the car. The control fuses are used as a protection to the operating coils of the magnet switches and also afford additional protection to the elevator equipment in the case of grounds or short circuits in the operating cables. The double coil overload movement is arranged to stop the elevator in case of overload and can be automatically reset by throwing the car switch to the off position. This gives a reliable indication as to whether the car is overloaded and by having the resetting feature in the car switch, it is possible to set this overload within the closest limits. This device therefore possesses an advantage over the hand operated circuit breaker in that the operator is not compelled to go to the switchboard in case a slight overload occurs. The only thing necessary is to lighten the load on the elevator. With a manually operated circuit breaker the operator, under these conditions, invariably increases the current setting of the breaker when he goes to the panel to reset it and, in case of continued tripping, eventually ties the breaker in; thus eliminating the overload protection which the circuit breaker is designed to give. The four step field weakening switch which is used on two speed equipments is a weight closed switch controlled by an air dash pot. It is positive in action and is operative both when inserting and when cutting out the field resistance, insuring smooth acceleration and deceleration of the motor.

Full Magnet Direct Current Controllers.—A typical direct current control apparatus of the full magnet type consists of several slate panels, mounted on an angle iron frame with all the connections made on the back of the board.

The solenoid switches mounted on the slate panels are arranged to perform the following functions:

1. To disconnect in the off position both sides of the line from the armature, series field, resistance, and brake magnet.

2. To accelerate the motor automatically by cutting out the armature starting resistance step by step, and also the series field with the last step of armature resistance (this by means of individual series relay control) giving smooth acceleration under all load conditions.

3. To control the speed of the elevator by cutting resistance in or out of the shunt field circuit of the motor, affording positive speed control under widely varying loads.

4. To bring the elevator quickly, but smoothly, from high to low speeds, regardless of load, making accurate stops at landings an easy matter.

5. To open the circuit to the motor should an overload current flow.

6. To apply the dynamic brake in the off position.

7. To test elevator at normal speed from the switchboard.

To these seven functions may be added, as a modification of the standard controller equipment:

8. To open the shunt field circuit in the off position of the controller.

Alternating Current Controllers.—There are many types of alternating current controller, the best known being of the full magnet variety.

As previously stated alternating current motors should preferably be limited to moderate speeds, because it is not feasible to employ dynamic braking. This means that the car must be slowed down and stopped by the application of the solenoid brake alone, and the speed must therefore be one that will permit

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NOTE.—Where old elevator equipments are being changed over to the full magnet system and the old motor is in such good condition that it is possible to use it with the new equipment, particular attention should be paid to the amount of speed variation that can be obtained from the old motor. Very few of the older elevator motors are designed for a wide range of speed variation by shunt field resistance.

this being done with safety and comfort under all the widely varying conditions met with in elevator service.

A typical alternating current full magnet controller consists of several slate panels mounted on an angle iron frame which serves also as a support for the resistance. Alternating current solenoid switches mounted on the face of the panel and

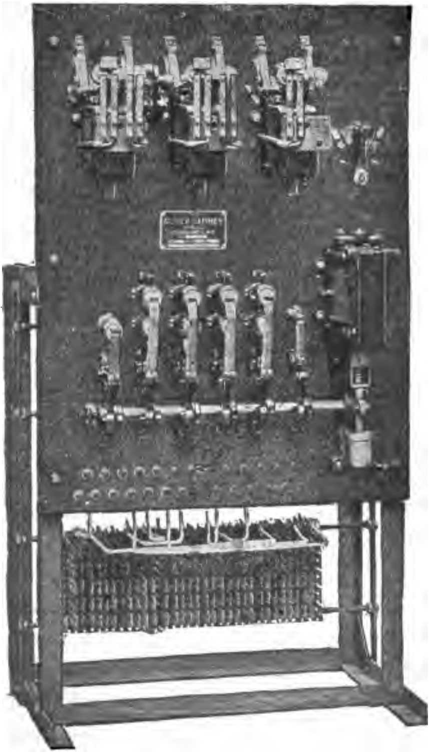
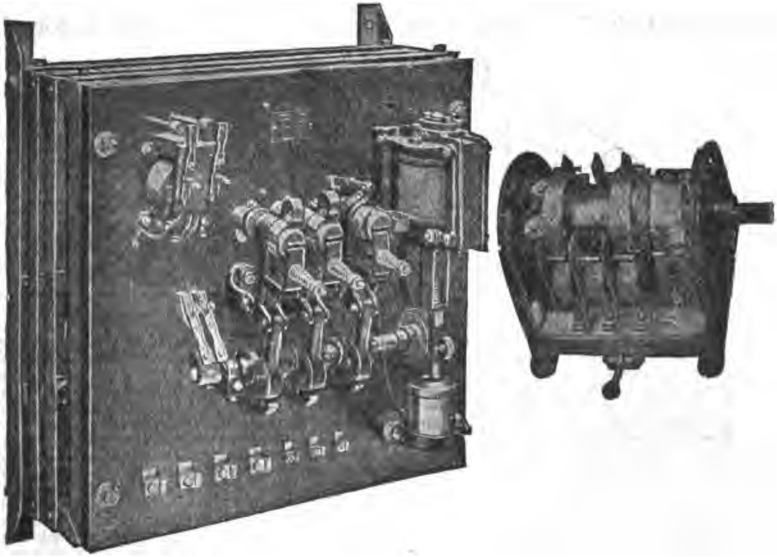


Fig. 5,793.—Cutler-Hammer, alternating current, reversible, single speed full magnet push button controller for slow speed passenger or freight elevators. It is suitable for two or three phase slip ring induction motors, 25 or 50 cycles, and also with self starting, single phase motors. The latter type motor should be provided with an interlocking connection to prevent quick reversals. Since there is no satisfactory and practicable method of reducing the speed of an alternating current motor under varying loads, the speed at which elevator cars may run when driven by such motors is limited and the problem is purely a matter of bringing the car to an easy and accurate stop. There are elevators driven by alternating current motors and operating satisfactorily at car speed of 275 to 300 feet per minute; however, in such cases the brake details have been worked out with extreme care so that a comparatively easy stop is made with widely varying loads, even for such a high speed. Ordinarily, however, it is not good practice to use alternating current elevator controllers for installation when the car speeds are likely to exceed 200 feet per minute. *In construction* of the controller here shown, the primary circuits are controlled by a double pole, solenoid operated main line switch and two double pole solenoid operated direction switches. The rheostat is of the solenoid operated crank acceleration type, retardation being effected by an adjustable vacuum dash pot. The starting resistance is of the cast grid type and is cut out in equal steps in each phase of the rotor winding, thereby keeping the phases in balance at all times. The rheostat and the main line switch are so interlocked that it is impossible to make a quick reversal with the starting resistance cutout. A mechanical interlock is also provided between the two direction switches so that both cannot be closed at the same time. Test buttons mounted on the panel permit of the car being operated from the switchboard.

connected to the resistance (all connections being made at the back of the board) are arranged to perform the following functions:

1. To disconnect the primary wires from the motor and brake solenoid in the off position of the controller.
2. To accelerate the motor automatically by cutting the starting resistance out of the rotor circuit step by step (using series relay control) and giving smooth acceleration at all loads.
3. To operate the elevator from the switchboard for test purposes.



FIGS. 5,794 and 5,795.—Cutler-Hammer alternating current, reversible, single speed, semi-magnet controller with separate reverse switch for slow speed passenger or freight elevators operated by self-starting, single phase, special elevator type motors. Fig. 5,794, self-starter; fig. 5,795, reverse switch. ***In construction,*** the self-starter is of the crank acceleration type, using individual carbon contact levers for each step of resistance. The rate of accelerating is under control of a vacuum air dash pot. ***In operation*** the contacts in the drum reverse switch are not required to break the motor currents, but are used to reverse the motor connections. Auxiliary contacts in the switch, handle, and control circuit of the self-starter and the main circuits are made and broken on a special quick make crank switch actuated by the accelerating solenoid. The special motor which must be used is provided with an interlocking contact on the motor which is closed only after the motor has practicaliy come to a standstill. Connection is made between this contact and the self-starter so as to insure reversal of the motor while running. The ordinary single phase, self-starting motor will not reverse from high speed unless this interlocking be provided. ***Adaptation:*** 25 to 60 cycles. Shaft limit switches may be installed in the elevator shaft if desired to stop the motor at the travel limits.

Alternating current controllers are illustrated in the accompanying illustrations.

The Transmission.—The term "transmission," as generally and erroneously used, denotes the system of gearing between the motor and drum; it properly includes the entire mechanism between the motor and car, that is, the gearing between motor and drum and the "final drive" or drum, cables and pulleys, for all

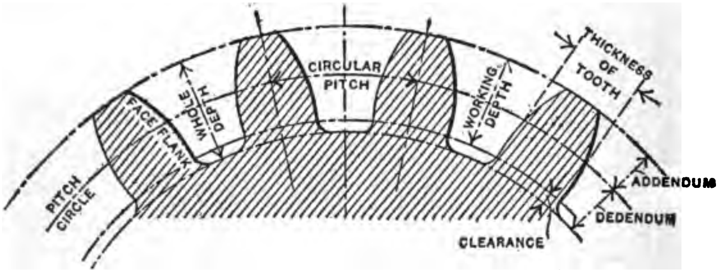


Fig. 5,796.—Gear tooth parts. ***Systems of spur gearing.*** Two systems of gear tooth are used for spur gears: the ***cycloidal*** and the involute. Of these, the involute system is the one more commonly used, especially for cut gearing. The standard involute gear tooth has a 14½ degree pressure angle, hence the rack meshing with gears cut according to this standard has straight sides inclined 14½ degrees from the vertical. ***Definition: Circular pitch*** *is the distance from center to center of two adjacent teeth along the pitch circle.* ***Diametrical pitch*** *is a number found by dividing the number of teeth by the pitch diameter;* that is, it gives *the number of teeth for each inch of pitch diameter.* ***Internal spur gears.*** The dimension of internal spur gears may be found by the same formulæ as those for external spur gears, except for the modification made necessary by the fact that the center distance in internal gearing is equal to the *difference* between the two pitch radii, instead of the *sum.* In addition, the term inside diameter takes the place of the outside diameter of external spur gearing. This diameter, of course, is the diameter of the hole in the blank before the teeth are cut. ***In laying out*** the shape of teeth for internal gearing, interferences are almost sure to be met with. The points of internal gear teeth must, therefore, be relieved to avoid interference with the flanks of the meshing teeth. ***Interference occurs*** also when the pinion has too nearly the same number of teeth as the gear. In this case there is a tendency for the points of the pinion and the gear teeth to strike as they roll into and out of engagement. To avoid this interference, the teeth must be cut by specially made cutters or shaped on a gear shaping machine.

NOTE.—The strength of gear teeth and the horse power that may be transmitted by them depend upon so many variable and uncertain factors that it is not surprising that the formulæ and rules given by different writers show a wide variation. In 1879 John H. Cooper (*Jour. Frank. Inst., July,* 1879) found that there were then in existence about 48 well established rules for horse power and working strength, differing from each other in extreme cases about 500 per cent. In 1886 Prof. Wm. Harkness (*Proc. A. A. A. S.* 1886), from an examination of the bibliography of the subject, beginning in 1796, found that according to the constants and formulæ used by various authors, there were differences of 15 to 1 in the power which could be transmitted by a given pair of geared wheel.

these devices are used to *transmit* power from the motor to the car. The same mistake is made in the case of the automobile by ill advisedly using the word transmission to denote only the gear set, whereas it properly includes the entire system between the engine and rear axle, viz: clutch, gear set, propeller shaft, universal joints, bevel gear and differential.

Accordingly in the case of the elevator, the transmission consists of

1. Gearing between motor and drum;
2. Drum;
3. Cables;
4. Pulleys.

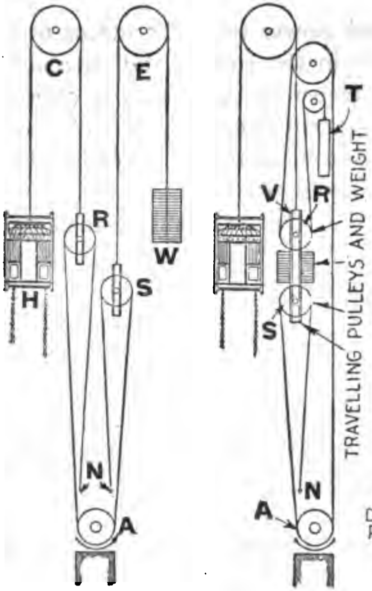
The term "electric engine" is used by elevator manufacturers to denote the motor, controller, drum and gearing between motor and drum. Presumably because these devices are usually incorporated in one unit, arises the erroneous usage of the term transmission.

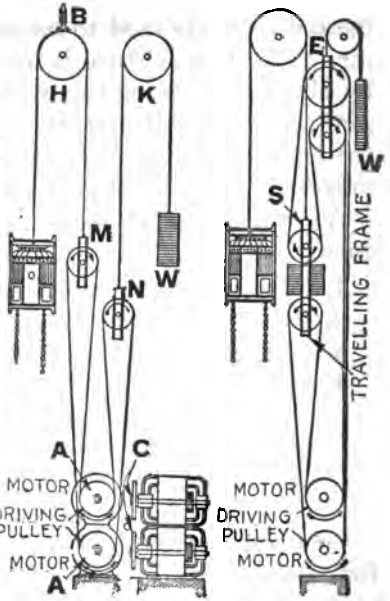
Gearing between Motor and Drum.—There are several forms of gear used to secure the velocity reduction between the motor and drum, necessary in most types of elevator. These may be classified as

1. Belt;
2. Chain;
3. Spur gear;
4. Herringbone gear;
5. Worm and wheel gear.

Belt Drive.—In factories or other places where line shafting is kept running continuously elevators are sometimes driven from a countershaft, the latter being belted to the line shaft.

Very often the elevator machine is driven directly from the line shaft, and as the line shaft always runs in the same direction the only way in which the elevator machine can be reversed is by the use of two belts, one open and one crossed, as is done in the case of a metal planer in a machine shop; this form of elevator drive has already been described.





Figs. 5,797 and 5,798.—Single motor traction drive with traveling pulleys. Fig. 5,797, primary form; fig. 5,798, modified form. This drive differs from the Fraser arrangement in that but one motor is used instead of two. The motor in this system runs at slow speed and, by means of the pulley A, on the armature shaft, drives a set of cable, which passes under this pulley, thence over the traveling pulleys R and S, and has its free ends anchored at NN. The frames of the traveling pulleys are respectively connected by cables passing over the upper pulleys C and E, with the car H, and the counterweight W. ***In the modified form,*** the two traveling pulleys R and S, are combined in a single frame V, and a tension weight T, is added as shown. ***In operation,*** the motor is controlled as usual from the car. It must be started to move the car and stopped to bring the car to rest. Both the car and counterweight move at half the peripheral speed of the driving pulley. If, however, the set of driving cable after passing over the pulley R and S, be led under a pair of stationary pulley and then have their free ends connected respectively to the traveling frames R and S, instead of anchored at the fixed points NN, the speed of the car and counterweight would be one-third the peripheral speed of the driving sheave. By further developing this plan, different ratios of car speed to motor speed can be obtained.

Figs. 5,799 and 5,800.—Fraser cable drive, designed to obviate the disadvantage of the large shaft space required for drum elevators in very high buildings, owing to the horizontal travel of the cables when winding. Fig. 5,799 primary form; fig. 5,800, modified form. ***In the primary form,*** the hoisting machine at C, consists of two motors, superimposed, each driving a set of endless cable by means of a pulley on its armature shaft. Two weighted sliding frames M and N, carrying pulleys, are driven by the endless cable. The frame M, is connected to the car O, by a cable passing over the upper pulley H, and the frame N, is connected to the counterweight W, by a cable passing over the upper pulley K. ***In the modified form,*** the traveling pulleys are combined in a single frame S, the tension on the endless cables being maintained by a weight W, acting on the pulleys in the frame E. ***In operation,*** when both motors are running at the same speed, and in opposite directions, the driving cables move without raising or lowering the car or counterweight. The motors,

Ques. Mention some objections to belt drive.

Ans. Slippage, breakage, and running off the pulleys.

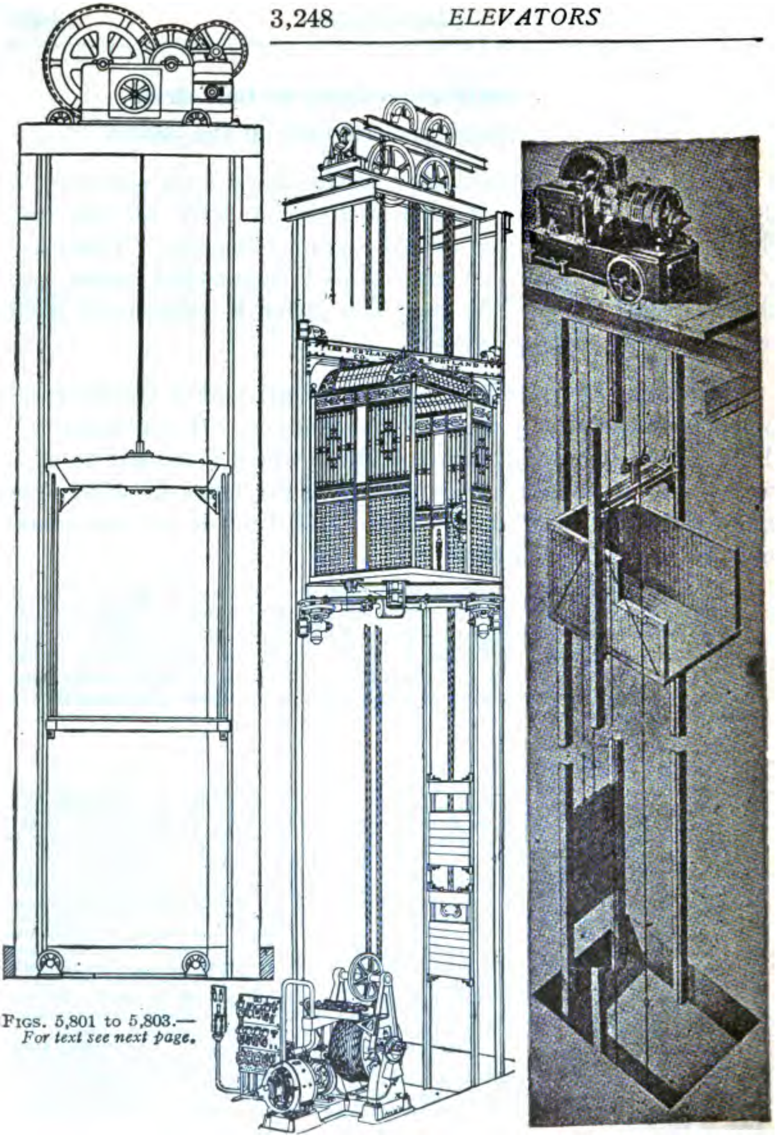
Chain Drive.—On some slow speed heavy duty elevators, a double reduction gear is used with chain drive for the first reduction and worm gear for the second reduction. There are various types of chain that may be used, such as link, roller, and the so called "silent" chain. The latter is extensively used because of its quiet operation.

Spur Gear Drive.—This well known method of transmitting power is extensively used in elevator practice. It is a "positive" drive, as distinguished from belt drive which is subject to slippage. For moderate speed motors or machines in which the speed reduction between the motor and drum is not too great, spur gearing is well suited.

Obviously, where great speed reduction is required, as in installation comprising a high speed motor and slow speed elevator it is not so well suited because of the large diameter of the drum gear required or the extra gears for double reduction necessary to obtain the necessary speed reduction. Clearly, such installations are best fitted with worm gear drive, as any speed reduction is easily obtained without the necessity of double reduction drive.

FIGS. 5,799 and 5,800.—*Continued.*

therefore run continuously in the operation of the system regardless of whether the car be moving or standing still. A magnetic brake B, on the overhead pulley H, is operated when the car is to remain motionless, so as to prevent any slight variation in the speed of the motors tending to move the car. When motion is to be imparted to the car, one motor is speeded up, and the other motor is slowed down, thus, there will be a difference in the heights of the two cable loops. This difference is taken up by the motion of the sliding frames which, in turn, transmit their motion to the car and counterweight, raising the one and lowering the other, or vice versa, depending upon which of the two motors be running the faster. The speed of the car in either case will be half the difference of the peripheral speeds of the driving pulleys. The motors are shunt wound, and run normally at 400 revolutions per minute. The speed of either motor can be increased to 520 revolutions per minute or diminished to 280 revolutions per minute by means of a rheostat in the car which introduces resistance in the field of one motor and cuts it out of the field of the other motor. With driving pulleys 19 inches in diameter, the operator can thus vary the speed of the car from zero to 600 feet per minute. Owing to the small diameter of the pulleys, a special kind of cable consisting of a steel wire core covered with manila or hemp is used to secure the requisite strength and flexibility. The advantages of the Fraser elevator, besides small shaft space required for its operation, are rapid acceleration and quick stopping, and the ability to reverse from full speed in one direction to full speed in the opposite direction without producing excessive strains or shocks in the apparatus. To counterbalance these features are the first cost and the operating cost of the system, both of which are greater than for the drum type of elevator.



FIGS. 5,801 to 5,803.—
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Herringbone Gear Drive.—This form of gear, sometimes called double helical tooth gear is a type in which right and left hand spiral teeth are both used.

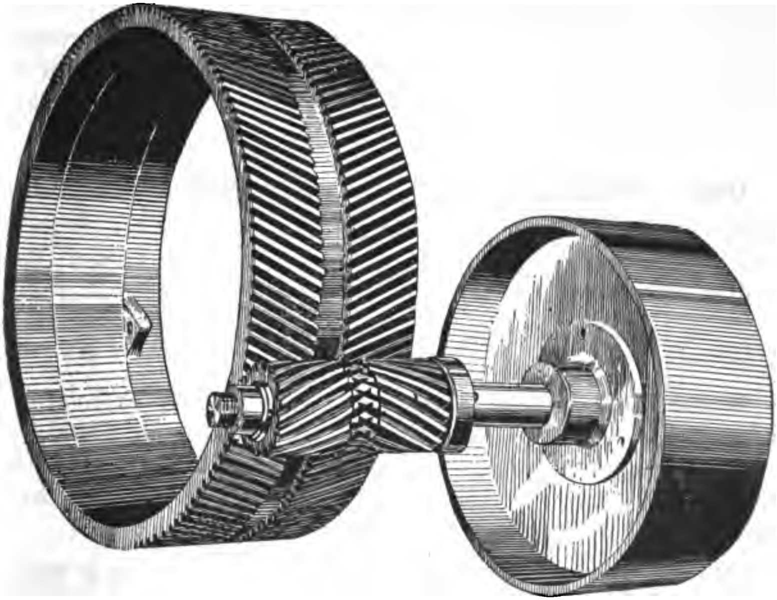


FIG. 5,804.—Guerney herringbone gear, pinion, and brake pulley. The ratio between gears is about 5 or 7 to 1, and the teeth in gear and pinion converge from the center of its face outward at an angle of about 23 degrees. There is nothing new about this type of spur gear, as it has been in use for mill purposes for at least a century. It was originally designed to impart a smoother motion to the driven machines and also to give greater strength to the teeth, but until recently the only method of producing it was by casting and, of course, cast gears were not applicable to elevator service. The advantages of the herringbone gear are a minimum of friction as compared with the worm and worm gear; smoother running than with the teeth cut straight across the face; and greater strength due to the diagonal position of the teeth, which allows a greater number of teeth to be in mesh with the pinion at one time.

Text for page 3,248.

FIG. 5,801.—Northern spur geared elevator machine for freight and foundry elevators. The frame for the hoisting machanism is self contained. A slow speed motor is used. The machine can be either over or under mounted or below the ceiling of any story with the rope carried over the pulleys.

FIG. 5,802.—Portland undermounted worm drive drum elevator showing machine, car, shaft, counterweights, and arrangement of cables and pulleys, also controller and safety devices.

FIG. 5,803.—Albro-Clem internal gear worm drive freight elevator.

The advantages of herringbone gears may be stated as follows: The action is continuous and smooth; there is no shock when the load is transferred from tooth to tooth, and therefore wear is practically eliminated, the bending action of the load on the teeth is less than with straight spur gearing; the gears work almost silently and without perceptible vibration; back lash is practically absent and herringbone gears can be used for high ratios and for great velocities.

Ques. Describe the Wuest system of herringbone gears.

Ans. The right and left hand sides of the gears are stepped half a space apart and do not meet at a common apex at the center of the face, as in the usual type of herringbone gear.

This stepped form wears more evenly under extreme loads than the ordinary type.

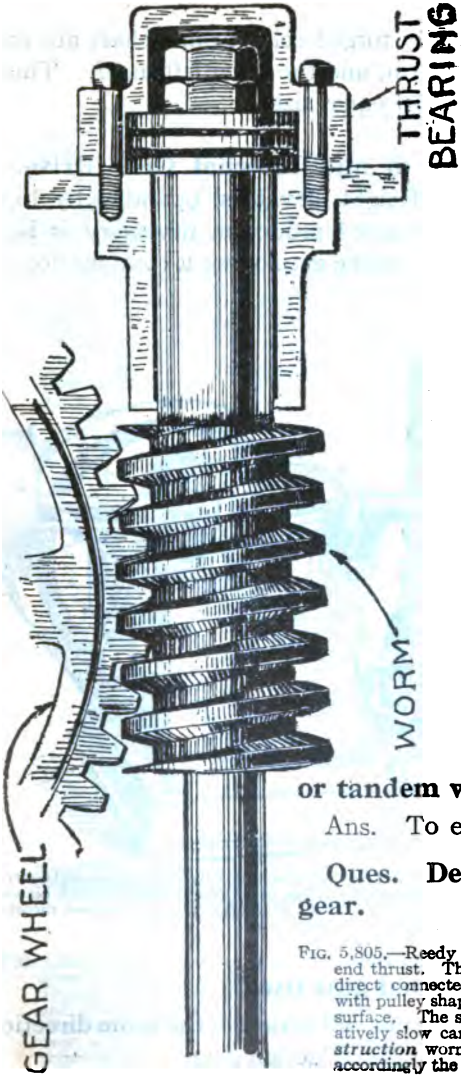
Worm Gear Drive.—This form of gear is very extensively used and is especially suited to slow speed elevators driven by high speed motors. A feature of worm gear drive is that it is self-locking because of the high velocity ratio, that is to say, no change in the loading of the car will produce movement.

In construction the gearing is enclosed in a cast iron box or casing which serves to protect the gears from dust and also to form a reservoir for oil used for lubrication. The worm is generally placed below the gear, in order that the worm may run in an oil bath. There are two kinds of gear:

1. Single gear;
2. Double or tandem gear.

An undesirable feature of the single worm drive is ***end thrust.***

NOTE.—The fundamental principle of the action of herringbone gear teeth lies in the fact that all phases of engagement take place simultaneously for every position of pinion and gear, providing the relationship between pitch, width of face and angle of spiral is such that it insures a complete overlap of engagement. Since all the phases of engagement occur simultaneously, it is evident that the load is partly carried by tooth surfaces in sliding contact and partly by surfaces in rolling contact. The portions of the teeth farthest from the pitch line, which engage with sliding action, tend to wear away more rapidly than the portions nearest to the pitch line. The pitch line portion, however, is always carrying part of the load and the effect of wear at the ends of the teeth merely is to throw more load on the center portions or in other words, there is a constant tendency to concentrate the load near the pitch line.



Clearly with a heavy load there is considerable pressure endwise on the threads of the worm which is accompanied by friction (loss of power) and wear, moreover a special form of bearing called a thrust bearing is required to take this end thrust.

Ques. Describe some forms of end thrust bearing.

Ans. For light service, discs of bronze and steel suffice to take the thrust; for medium duty ball bearings should be used; and for heavy duty, roller bearings.

The details of construction are shown in the accompanying cuts.

Ques. What is the object of a double or tandem worm gear?

Ans. To eliminate the end thrust.

Ques. Describe a double worm gear.

FIG. 5,805.—Reedy single worm drive with ball bearing end thrust. The shaft on which the worm is cut is direct connected to the motor through a coupling with pulley shaped flange which is used as a braking surface. The single worm drive is suitable for relatively slow car speed and light loads. *In construction* worm drives are arranged to run in oil, accordingly the worm is placed below the gear wheel.

Ans. Two worms, usually forged solid to one shaft are employed; one, a right hand worm, and the other left hand. These worms mesh with two gears of equal size.

Double Reduction Worm and Internal Gear Drive.—For very slow heavy duty freight elevators, operated by high speed motors, the excessive speed reduction necessary is best obtained by double reduction drive employing a combination of worm and internal spur gear.

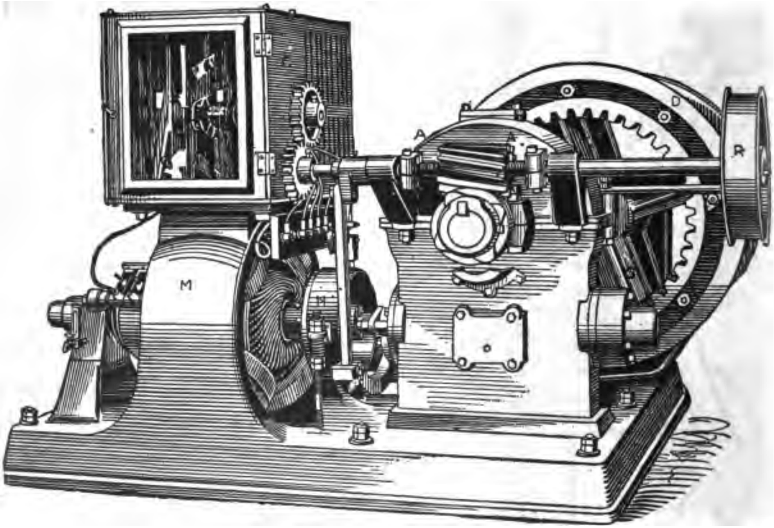


Fig. 5,806.—Warner internal spur gear freight elevator machine, fitted for mechanical control. The gear spider S, and drum D, are made in one casting with a heavy cast iron neck between them. On top, the motor M, is the controller box C, containing the switches and rheostat. N, is the brake, R, shipper pulley, and A A, the limit stop.

Ques. Why is an internal gear used?

Ans. In order that the drum will rotate in the same direction relative to the worm as in single reduction gear.

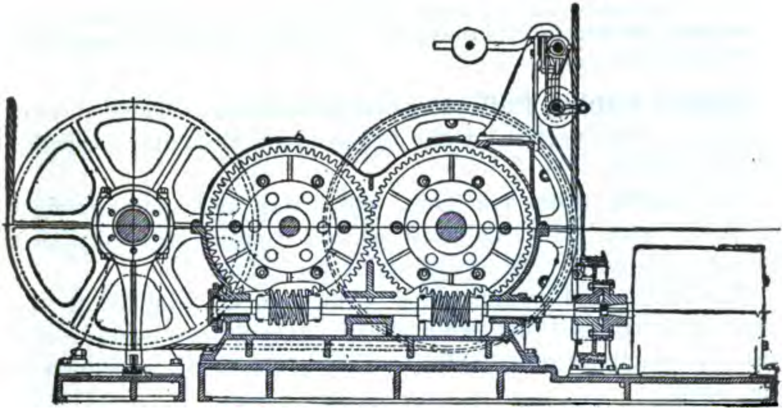


Fig. 5,807.—Tandem worm drive machine with independent concave face gears meshing with the worm as shown by the portions of the larger gears cut away above the worms. As shown, there are four gear wheels bolted together in pairs, the two larger ones meshing with each other, and the two smaller ones with the worms.

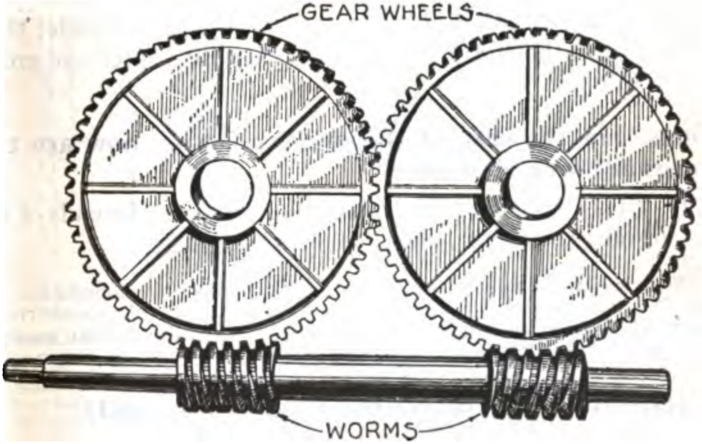


Fig. 5,808.—Reedy tandem worm drive. This type differs essentially from the single worm drive in that intermeshing right and left hand gears are used in place of the single gear. The use of the double gear has the advantage of dividing the pressure between the worm and gear so that greater loads and speeds are obtainable than are advisable with the single gear. The manner in which the gear wheels and worms intermesh produces, moreover, a three point contact which permits the gearing itself to compensate for any end thrust of the worm shaft, thus eliminating the necessity of thrust bearings.

It is desirable that the drum in lifting the load should revolve so as to bring the thrust of the end of the worm shaft toward the back end of the gear case.

Drums, Cables, Pulleys, Counterweights.—These devices constitute that portion of the transmission that may be called the *final drive*.

On winding drum machines, the lifting and counterweight cables are attached to the drum, which is spirally grooved with a concave groove to receive and guide the cables.

The lifting and counterweight cables are so attached to the drum and arranged that, while the lifting cables are being wound up, the counterweight cables are being unwound, as shown in fig. 5,802.

The idler pulley slides from side to side as the cables wind on or off. From the illustration it is clear, that they alternately use the same grooves in pairs. These grooves or scores as they are called, are, in the case of the overhead type, so made, that they run from the end of the drum toward the center one grove on each side.

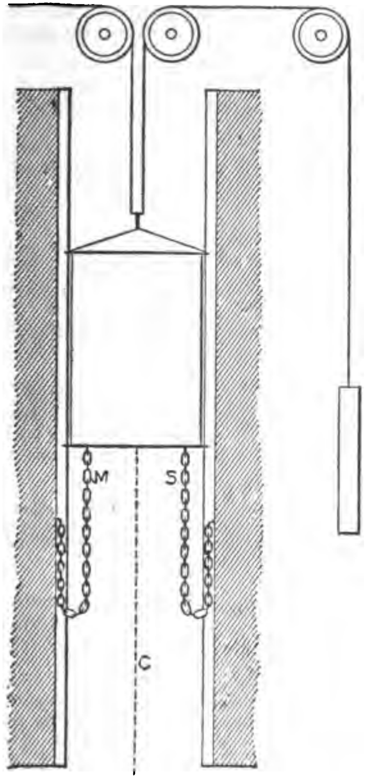
Ques. In the case of the overhead type, how are the grooves or "scores" made?

Ans. They are so arranged that they run from the ends of the drum toward the center, one groove on each side.

When the engine is set to one side of the shaft, either on a foundation or a suitable frame on one of the other floors of the building, the grooves run in pairs side by side from one end of the drum to the other and are made to lead right hand or left as the conditions require.

Ques. How are the counterweights arranged?

Ans. Two weights are used, as in fig. 5,802, one, which is attached to the drum to offset a certain percentage of the load to be lifted, and another to counterbalance the car. The latter weight travels in the same runways as the drum counterweight, grooves or channels being cast in this upper weight to allow the supporting cables for the lower weight to pass through. The cables from the upper or car counterweight pass up the shaft and over the pulleys set at the top of the shaft and thence down to the car.



How to Run an Elevator.—Any one who has tried to stop an elevator at a floor will agree that it cannot be done without experience; however, the following directions as to the proper procedure in operating and taking care of the plant will be found of value.

Fig. 5,809.—Compensating chains to counteract the varying factor introduced while the car is in motion by the changing length, and therefore changing weight, of the hoisting rope between the top of the car and its overhead pulley and also of the counterbalance cable between the counterweight and its overhead pulley. In installations where the cars make long trips, the weight of the ropes that ordinarily would have to be counterbalanced varies between wide limits. By the use of balancing chains hung from the bottom of the car, the problem is simply and effectually solved. These chains do not alter the total amount of power required per trip, but make the consumption of power nearer uniform throughout the trip. There may be but one balancing chain attached directly beneath the center of the car and allowed to hang all the way down the shaft as at C, or else two chains M and S, each of equal weight and about half the length of the chain C, may be attached to the bottom of the car and fastened at the middle of the shaft as shown, so that they hang in a loop in the shaft and travel up and down with the car. In either case the total weight of the balancing chain or chains must be equal to the weight of rope to be balanced. The chief objection to chains as compensators is the noise.

Before Starting.—The main switch connecting the motor with the supply circuit must be closed. This switch should not be closed, however, until it is positively known that the hand rope, pilot wheel, lever, or switch of the operating device in the car is in its off position.

Starting.—In all cases the car should be started gradually, although in order that a reasonable average speed be maintained between floors the acceleration must be rapid.

In starting, considerably more power is required than after the car has reached its normal speed, and the more abrupt the start the greater this abnormal power and the greater the stress in the various parts of the equipment.

Stopping.—An abrupt stopping of the car produces a severe stress on the braking apparatus. If the stops be made within the distance that the operator can see the landing at which he aims, the best results will be obtained for moderate speed cars. This allows the operator about eight feet in which to bring the car to a stop from full speed. A skillful operator can readily do this, but an unskillful one may require a much longer distance.

Sudden Reversal.—On account of the waste of power and the strain on the apparatus, it is advisable not to suddenly reverse the direction of travel of the car; also, to bring the floor of the car on a level with the landing at the first stop, not run past and then back up, or stop too soon and thus have to start and stop again.

By giving attention to these points, not only will the power used, and therefore the operating expense be reduced, but the useful life of the motor starter contacts will be prolonged. These contacts suffer most from the sparking and flashing produced by switching off the current when the motor has just started or while it is running very slowly.

Motor Starter Contacts.—These contacts should always be kept smooth and bright. A piece of fine sand paper rubbed over them is the best means of producing the desired result. After sand papering, the loose particles should be blown out with a bellows.

The bearings and cams of the motor starter should be kept clean and well oiled, and if a dash pot be provided to prevent the contact arm moving over the contacts faster than is necessary to secure the proper acceleration of the motor, this should be adjusted so that the arm will descend in from five to seven seconds.

As the retarding action of the dash pot may be overcome by gravity, a spring, magnetic attraction, or by the motion imparted from the motor, the shafting, or the elevator machine, the method of adjustment will depend upon which form of motor starter be used.

Caution in Adjusting.—An important point to remember in connection with the cleaning, oiling, or adjusting of the motor starter, and in fact in connection with the cleaning, oiling, or adjusting of any parts of the elevator equipment, is to open the main switch connecting the motor to the supply circuit before commencing these operations; this will tend to prevent accidents of an electrical or a mechanical nature.

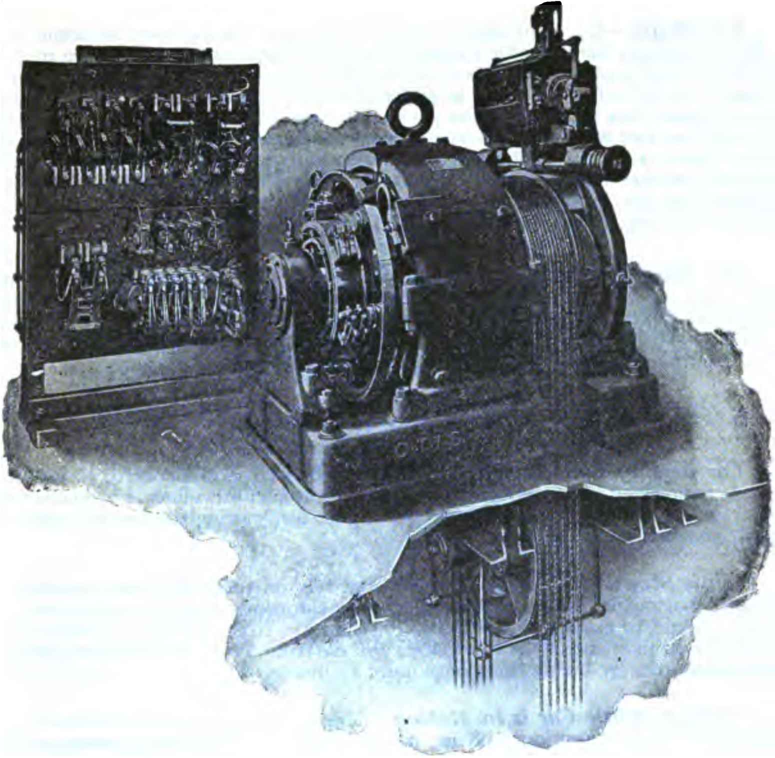


FIG. 5,810.—Otis 1 to 1 over mounted traction elevator machine, consisting essentially of a slow speed shunt wound motor, a traction driving pulley, and a magnetically released spring applied brake. Full magnet control is used. The motor is so governed as to prevent excessive speed regardless of load. Automatic slow down near the travel limits is secured, attained by two multi-arm switches located on the car, one for the up and one for the down motion. These switches are operated by cams in the shaft that open the contacts, one after the other, as the car approaches the limits of travel. This automatic feature being independent of the operator in the car, is effective even though the car operating device be left in the full speed position. The usual safety devices installed in connection with modern apparatus, are used with this type of elevator, including speed governors, wedge clamp safety devices for gripping the rails in case of the car attaining excessive speed, and pressure switches. One safeguard resulting from the arrangement and the method of driving the cables, is the decrease in traction which follows the bottoming of either the car or the counterweight on their oil buffers. This minimizes the lifting power of the motor, until normal conditions are resumed. Inasmuch as in any properly constructed elevator the roping is so arranged that the counterweight will rest on its oil buffer before the car reaches the overhead work, or vice versa, it therefore will be seen that the above mentioned decrease in tractive effort is a very valuable and effective safety feature inherent in this type of elevator.

Car Stops.—If, in the operation of an elevator, the car stop for some unknown reason, the operator should at once shift his controlling device in the car to the off position. If, then, upon shifting the controlling device again to start, the car refuse to move in either direction, some one of the following occurrences has probably taken place: It may be that the car or counterweight has met with some obstruction and the slack cable device has operated; that there is a poor contact in the switch or connections; that the fuse or circuit breaker has opened the motor circuit; or that the current has been turned off the supply wires. In any case, the motor should be examined before starting, to see that no damage has been done to it.

Car Stops Between Landings.—When this happens, owing to a failure in supply of power, an effort should be made to have the main switch opened, the brake released, and the worm shaft turned either by pulling on the brake pulley or with a wrench on the end of the armature shaft so as to bring the car to a floor landing and allow the passengers to get out.

In some elevator motors, the free end of the armature shaft is purposely made square to facilitate turning the shaft with a wrench as just mentioned.

Car Beyond Control.—If the operator find he has lost control of the car and cannot stop it, he should not become frightened but allow it to make the full run, relying on the limit stops to automatically bring the car to a standstill at either end of its travel.

Limit Stops.—The operator should not rely on the limit stops to make a top or bottom landing, but should operate the controlling device in the car as he would to make any intermediate landing. It is advisable, however, to test the adjustment of the limit stops and determine if they remain in proper working order by trying them once daily by means of the car.

Caution While Car is in Motion.—The operator should never leave his car while it is in motion, and he in turn should never allow a passenger to enter or leave until the car has stopped at a landing.

The majority of elevator accidents have resulted from carelessness in observing this simple rule, showing that more attention should be given it by operators than heretofore has been the custom. As the operator opens the doors at a landing he should call out "up" or "down," depending upon the direction in which the car is making the trip, and while he should allow ample time for passengers to reach the car from wherever they may be standing, it may be necessary in certain cases to add, "step lively, please."

Leaving Car for the Night.—When the elevator is left for the night, the car should be brought to the lowest landing and allowed to remain there. Care must be taken to open the main switch connecting the motor to the supply circuit, before leaving the premises. In fact, whenever the car is to be left idle for any length of time, this switch should be opened to prevent any possibility of the motor starting up and causing damage.

CHAPTER 89

CRANES AND HOISTS*

**The subjects of steam hoists, pile drivers, etc., have been treated at considerable length in chapters 27 and 28 (Guide No. 2) and the matter here presented under "Hoists" is not a repetition, but items not covered in the chapters just mentioned.*

By definition, a crane is *a machine for lifting, lowering and moving a load in a horizontal direction*, as distinguished from a hoist which simply lifts and lowers a load.

The numerous and diverse conditions of service require a multiplicity of type, and accordingly cranes may be classified:

1. With respect to the motive power, as

a. Steam.
b. Pneumatic.
c. Hydraulic.
d. Electric.

2. With respect to the character of the horizontal motion, as

a. Rotary
  - swinging cranes
  - jib cranes
  - column cranes
  - pillar cranes
  - pillar jib cranes
  - derrick cranes
  - walking cranes
  - locomotive cranes

b. Rectilinear
  - bridge cranes
  - tram cranes
  - traveling cranes
  - gantry cranes

c. Combination rotary and rectilinear.

In addition to these, there are some miscellaneous types known as

1. Sheer legs.
2. Transporters.
3. Telphers {cableways, mono-rail systems

The following definitions of the various types show the inherent features of each:

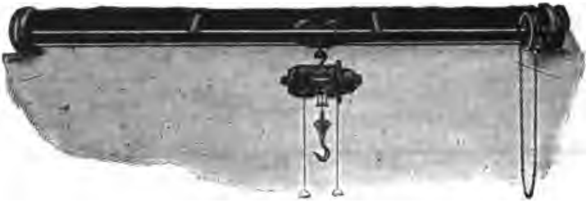


FIG. 5,811.—Northern hand power traveling crane designed for use where service is infrequent and where speed is not essential, and especially where low first cost is desired. The crane is operated from the floor by means of hand chains. but a special form is made for platform operation.

Bridge cranes.—Having a fixed bridge spanning an opening and a trolley moving across the bridge.

Column cranes.—Identical with the jib cranes, but rotating around a fixed column (which usually supports a floor above).

Derrick cranes.—Identical with jib cranes, except that the head of the mast is held in position by guy rods or stiff legs, instead of by attachment to a roof or ceiling.

Gantry cranes.—The same as a traveling crane except that the bridge member is supported on structural legs of suitable height, which are provided with wheels and suitable gearing, so that the crane may be propelled bodily along the tracks which are on the ground.

Jib cranes.—Having rotation and a trolley traveling on the jib.

NOTE.—***Drum versus Magnetic Controllers.*** Both hand and magnetic control equipments are in general use. The former are satisfactory for small and medium size motors and consist simply of a drum type controller with a set of separate resistances. For large size motors too much physical effort would be required to move a controller of the necessary size and the magnetic control should then be selected. A magnetic control equipment consists of a master controller, a contactor panel and the resistances. The contactor panel contains the contactors for cutting in or out the resistances, the interlocks and the current limit relays for automatically controlling the sequence and rapidity with which the contactors operate. The master controller handle can be thrown to the full speed position quickly without causing an overload on the motor, since the current limit relays automatically prevent the contactors cutting out the resistances too rapidly.

Locomotive cranes.—Consisting of a pillar crane mounted on a truck, and provided with power capable of propelling and rotating the crane, and of hoisting and lowering the load.

Pillar cranes.—Having rotation only, the pillar or column being supported entirely from the foundation.

Pillar jib cranes.—Identical with the last, except in having a jib and trolley motion.

Rotary bridge cranes.—Combining rotary and rectilinear movements and consisting of a bridge pivoted at one end to a central pier or post, and supported at the other end on a circular track, provided with a trolley moving transversely on the bridge.

Swinging cranes.—Having rotation, but no trolley motion.

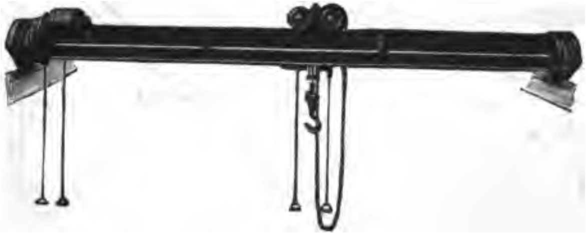


FIG. 5,812.—Northern type of electric hoist crane; made in sizes ½ to 10 tons and are intended for moderate service.

Tram cranes.—Consisting of a truck, or short bridge traveling longitudinally on overhead rails, and without trolley motion.

Traveling cranes.—Consisting of a bridge moving longitudinally on overhead tracks, and a trolley moving transversely on the bridge.

Walking cranes.—Consisting of a pillar or jib crane mounted on wheels and arranged to travel longitudinally upon one or more rails.

Essentials of Rotary Cranes.—In this type of crane, the construction is such as will permit the load to be lifted, lowered, and moved radially. An example of rotary crane is shown in fig. 5,813, which illustrates the essential features of a locomotive jib crane.

Ques. What area is served by a locomotive jib crane?

Ans. It is equal to twice the maximum radius of the jib, and a length depending on the length of track laid.

Ques. What is the effective radius of the jib?

Ans. Its projection on the horizontal plane passing through the pivot on the lower end of the jib.

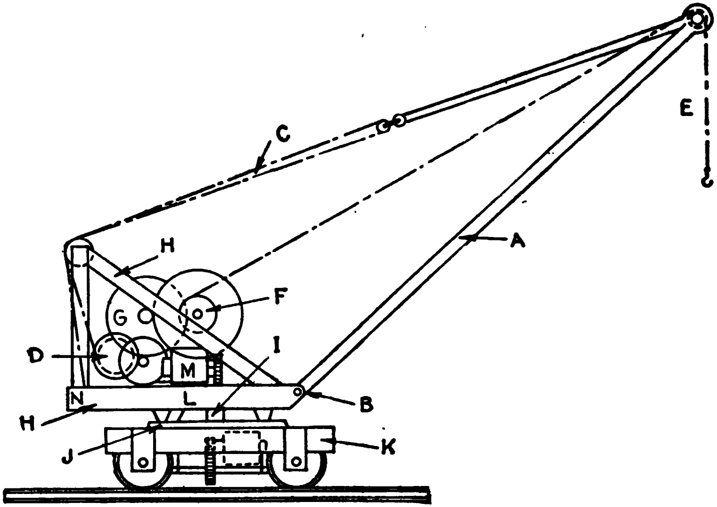
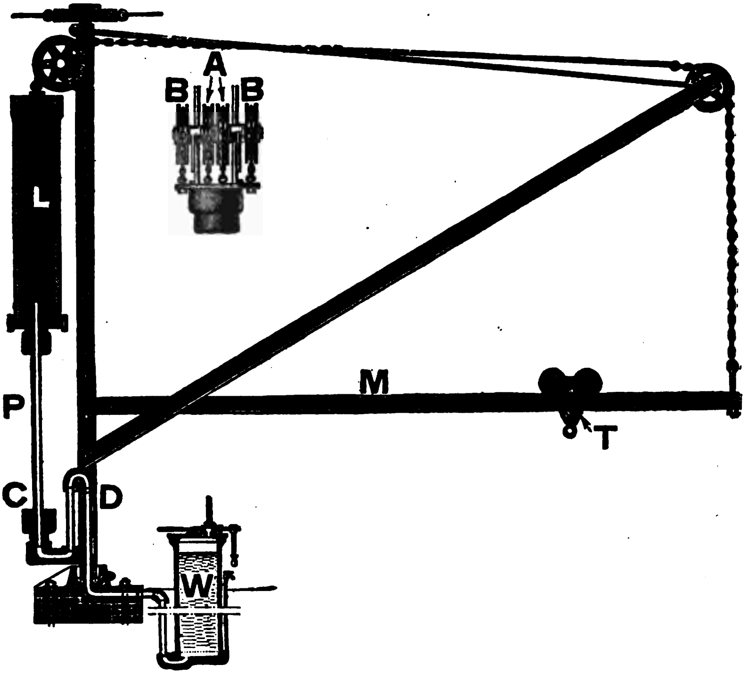
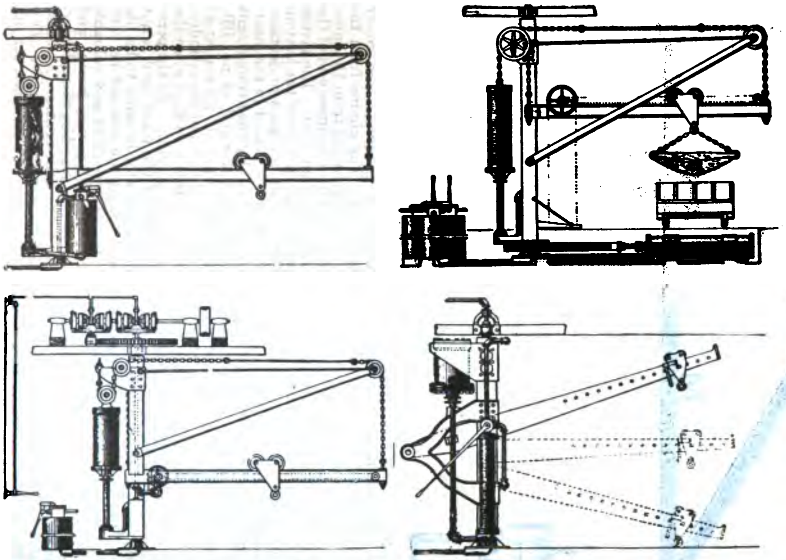


FIG. 5,813.—Electrical locomotive jib crane. ***The essential parts are:*** A, jib; B, jib pivot; C, rope gear serving as a brace for jib, and which controls the radial position of jib; D, jib shifting drum; E, hoisting rope leading from hook; F, hoisting drum; G, hoisting motor; H, framing; I, pin; J, turning or slewing wheel; K, truck; L, pinion; M, turning and propelling motor. As shown in the figure, the hook, which engages the load, hangs from the end of the jib A, which is supported by the piece B, and rope C, which leads to the drum D. By winding in or paying out the rope C, the radius of the jib in the horizontal plane can be increased or diminished. The rope for hoisting the load is brought over a pulley at the head of the jib and led to the drum F. Drums D, and F, are usually arranged to be driven from one motor G, clutches being so arranged that when the motor is in gear with the one drum, it is out of gear with the other. The jib and hoisting gear are carried by the framing H, which turns upon the pin I, the turning or slewing being accomplished by means of the wheel J, which is secured to the platform of the truck K, and pinion L, (carried by bearings in the framing H), which is driven by the motor M. It is usual for the framing to be capable of making a complete circle. The motor M, is also used to drive the truck along the rails. A vertical shaft driven from this motor passes through the pin I, and drives one or both of the axles by means of bevel gear. Clutches are provided so that the motor M, may be used for slewing or traveling. The load is balanced by the weight N. A foot plate for the operator is provided on the framing just in front of the balance weight, and the controllers and clutch levers are within easy reach.



FIGS. 5,814 and 5,815.—Ridgway steam hydraulic *cylinder* or geared elevator. Ridgway steam hydraulic balanced crane. ***In construction,*** a vertical moving jib M, carrying a free trolley T, is suspended by four short and heavy chains, two at each end. The chains from the outer end pass over wheels on the end of the inclined braces, and the chains from the inner end pass over wheels on the mast, and all four chains are connected with the upper end of the cylinder either by being attached to it or by passing around wheels on top of it. The piston rod of the cylinder is hollow. Its lower end is securely fastened to a projection of the bottom gudgeon. The passage way of the piston rod is continued through the gudgeon projection, and is thence connected with an inverted U shaped stuffing box which is placed in the mast. From this stuffing box the pipe leads out through the foundation plate. By the arrangement of the chains (see small cut, fig. 5,815, where A, are the chains to outer end of jib, BB, chains to inner end of jib, the cylinder always tends to hang perfectly plumb, no matter at what point on the jib the load may be). The chains being fastened to the end of the cylinder, the jib has the same motion as the cylinder. From this construction it is seen that when the cylinder is pressed down, the rod, the jib and its trolley will rise in proportion. As the pressure is used to operate the crane is the usual steam or air pressure of the plant, and is not often more than 60 to 100 pounds, the cylinder must be large in diameter in order to be big enough to lift the load. This large and heavy cylinder would offend the eye and be very objectionable were it not that its size and weight are used for the important and valuable service of balancing the jib and all the overhang of the crane. The jib is very heavy, and would be a good load of itself for a low pressure to handle were it not balanced by the cylinder. It will also be noted that the wheels upon the mast are set back from the centre. At these wheels is concentrated all the weight of the cylinder and half the weight of the jib. This weight counterbalances the inclined struts or braces and other parts. Thus, when set up, the whole crane is in balance and there is no overhang.



FIGS. 5,816 to 5,819.—Some modifications of Ridgway steam hydraulic crane showing flexibility of the system. Fig. 5,816, shows crane with the water cylinder and operating valve placed on the mast and turning with the crane. The steam is brought in through the top gudgeon, and out through the bottom. This can be reversed or both through either gudgeon. Fig. 5,817 shows crane made to rotate by power. This is done by placing a cylinder below floor level with a rack, engaging a pinion on bottom pintle. The swinging cylinder may also be placed overhead. The crane is shown carrying a cake of blast furnace cinder. In places where the nature of the ground prevents the men walking around with the crane, this power swing is desirable. Fig. 5,818 shows crane with power swinging and power trolley racking mechanism. In this case an overhead shaft is provided. This is a slow turning shaft. The different motions are obtained by means of friction clutches, which are thrown into action by rods leading to the operator, or a small steam cylinder may be used for this purpose. This makes a good arrangement for pipe foundries and similar situations. The clutches are male and female frictions, which give cushion effect. Fig. 5,819 shows crane designed to give a lift of the load nearly equal to the entire head room. The lifting cylinder is of very short stroke and is placed back of the mast. The water cylinder is placed on the side of the mast. The beam, which is moved by the cylinder, carries a trolley provided with a stout latch, which locks into the holes in the beam. When the beam has been brought to a horizontal position, the trolley can be traversed on the beam. In this way all the space within the radius may be covered. On account of the motion of the beam being many times that of the actuating piston, it is vital that the motion of the latter be under control and perfect.

Ques. What is the most economical position of the inclined brace in a jib crane?

Ans. The position in which the inclined brace intersects the jib at a distance from the mast equal to $^4/_5$ of the effective radius of the jib.

Essentials of Rectilinear Cranes.—This form of crane differs from the preceding type in that the load is moved linearly instead of radially. The essential features of rectilinear cranes are shown in fig. 5,820, which illustrates a rectilinear crane of the traveling type.

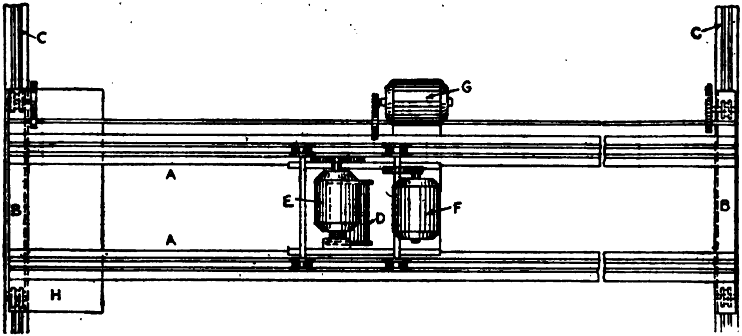


FIG. 5,820.—Electric traveling crane. ***The parts are:*** AA, cross girders known as the *bridge*, BB, end carriages; CC, elevated track structure or *gantries*; D, hoisting drum; E, hoisting motor; F, transverse propelling motor; G, longitudinal propelling motor; H, cage or operator's platform.

In construction, a pair of cross girder AA, known as the bridge, are supported on the end carriages BB. The wheels of the end carriages run on rails mounted on elevated structures or *gantries* CC. The purpose of the crane is to lift, transport, and deposit loads anywhere within an area a little less than the width between the gantries and of a length depending on the length of the gantries. Rails are laid on the cross girders AA, and a crab or trolley runs on these rails.

The trolley has two motions, each driven by its own motor.

The hoisting motion, for lifting and lowering the load, consists of the drum D, driven through suitable gearing by the motor E. To traverse the crab along the cross girders, the motor F, drives one pair of wheel through gearing. For the purpose of traveling the crane along the gantry, the motor G, is mounted at the center of one of the cross girders, and from each end of the motor, a shaft is led to drive one wheel in each of the end carriages. The traveling motor is mounted at the center of the cross girder to obtain an equal amount of twist in both parts of the shafting so as to avoid cross wind.

Essentials of Combined Rotary and Rectilinear Cranes.—A modification of the traveling crane, which combines the functions of the two classes, rotary and rectilinear, consists in pivoting one end of the bridge of a traveling crane and supporting the other end on a circular gantry as shown in fig. 5,821.

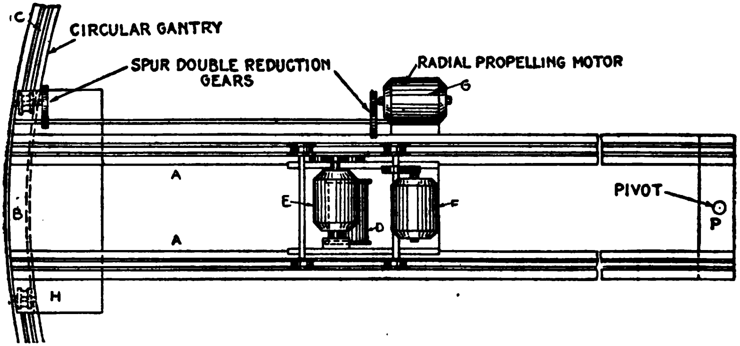
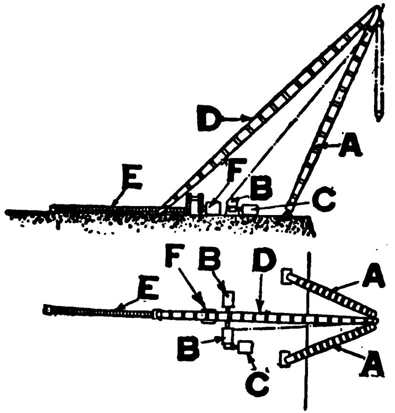
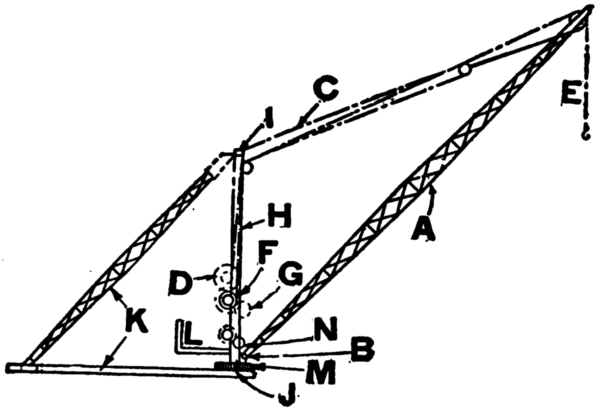


FIG. 5,821.—Electric combined rotary and rectilinear crane. *In construction* most of the parts are identical with those of fig. 5,820, and the letters on these parts are the same for each figure. This type differs from fig. 5,820, in the replacement of one gantry by a pivot P, and the other straight gantry by a circular gantry which may be either an arc or a complete circle as desired. One end of the bridge is pivoted at P, and at the other end, a section of the circular gantry is shown. The circular gantry may continue all the way around or only for a short arc, as may be desired. The figure clearly shows that the rotary motion is obtained by operating motor G, and the rectilinear motion, by motor F, while hoisting and lowering is effected by motor E.

The illustration shows that most of the mechanism is identical with that of the traveling crane.

Essentials of Transporters.—By definition a transporter is *a lifting and transporting machine designed to carry loads between two fixed points.* It is used chiefly for handling comparatively light loads at quick speeds and employed largely for the conveyance of materials such as coal in bulk. For the latter service





FIGS. 5,822 and 5,823.—Sheer legs. This is a type of lifting appliance used for handling extremely heavy loads such as ship's boilers and heavy guns. The load rope passes over a pulley at the head of the legs A, and is led to the winding drum B, which is driven by the motor C. The bottom of the back leg D, is traversed by a screw E, driven by the motor F, so as to traverse the load in or out. Occasionally a second hoisting drum and motor are provided to handle light loads at quick speeds. It will be noted that with this type of crane, loads can only be picked up and deposited along a horizontal line which is a continuation of the center line of the screw.

FIG. 5,824.—Electric derrick crane. The load hangs from the end of the jib A, which is supported by the pin B, and rope C, which leads to the jibbing drum D, by which the jib can be lowered. The load rope E, is led to the drum F. Drums D and F, are driven by motor G. A clutch is provided by which the drum D, may be put in or out of gear with drum F. When D, is is out of gear, the drum F, is used to lift or lower the load. When the two drums are clutched together they run in opposite directions, so that when drum D, is hoisting the jib, drum F, pays out the load rope, and vice versa. Thus, whether the jib is being lifted or lowered, the load remains steady, and simply runs in or out in a horizontal line. The jib and the motors and gearing are carried by the vertical mast H, which turns in bearings I, J, in the framing K. The driver's platform L, is also attached to the mast, and the various controlling switches and levers are placed on this platform. To slew the mast and jib, a toothed wheel M, is fastened to the framing and gearing. With this is provided a pinion, the shaft of which is carried in bearings on the mast, and is driven by the slewing motor N. This type or crane will serve an area having a radius equal to the maximum horizontal radius of the jib, and forming a segment of a circle embracing an arc of rather less than 270 degrees.

it is provided with an automatic grab instead of a hook. Fig. 4,221 shows the essential features.

Ques. How long does a complete cycle take in this type of apparatus?

Ans. From one-half to one minute.

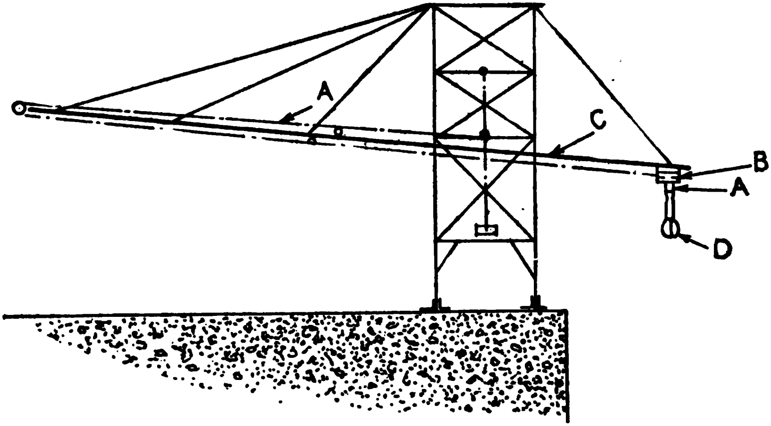


FIG. 5,825.—Electric transporter. ***The parts are:*** A, load rope; B, carriage; C, beam; D, grab. ***In operation,*** the grab being full, the electrically driven drum winds in the load rope A. The carriage B, being held by a trigger at the bottom end of the beam C, the winding in of the rope lifts the grab. When it is heaved right up to the carriage, it locks itself to it, and at the same time lets go the trigger. The carriage is pulled along the beam, but as the rope is now single purchase, the carriage is pulled along at double the speed at which the load was hoisted. On arriving at the top end, the carriage is held by a trigger and the grab is freed from the carriage. The motor is now reversed, and the grab, after being lowered a given distance, discharges its contents. The motor is again reversed, thus hoisting the grab up to the carriage, to which it locks itself and frees the trigger. On reversing the motor, the carriage runs down the beam, and at the bottom end is caught by the trigger, while the grab is released and continues to run down till it plunges into the material, thus completing the cycle.

Ques. What is the grab load?

Ans. From one to one and one-half tons.

NOTE.—***Crane Motors.***—For driving the traveling, traversing, and slewing motions of crane, series wound motors of a generally similar type to those used for electric traction give satisfactory results, this work being in fact a simple class of electric traction. The driving of the hoisting motion presents a more difficult problem, for though it is easy to lift the load up, it is not always so easy to get it down again in a satisfactory manner.

Automatic Electro-magnetic Brakes.—It is customary to fit the hoisting motion with an electro-magnetic brake. This may consist of a band brake which is normally kept on by a spring or weight and released by an ironclad solenoid, or it may be a disc brake in which the discs are normally pressed together by a spring, an electro-magnet being provided to pull back the pressure plate and release the discs.

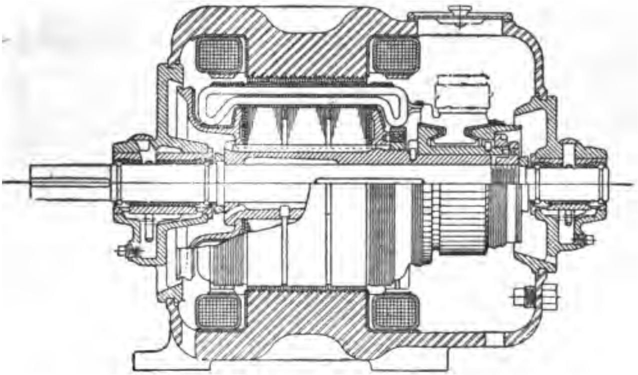
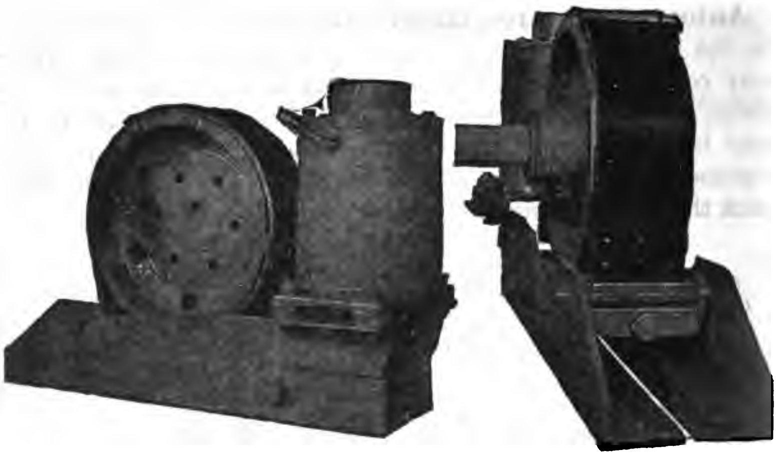


FIG. 5,826.—Sectional view of Shaw type Z crane motor. The frames are of cast steel split diagonally and when assembled with bearings completely enclose the armature. The motor has four salient poles cast integral with the frame and so shaped that the field coils can easily be put in place. The brake is attached to the lower half of the frame so that the motor can be taken apart without disturbing it except that the band must be removed by taking out the two pins holding same.

The coil of the solenoid or electro-magnet is in circuit with the hoisting motor, so that when current is switched on to the motor, the brake is released, and when it is switched off, the brake is applied. This makes an excellent safety device, but as it can only be off or full on, it cannot be used to regulate the descent of the load when lowering.

In cases where the driver has access to the gear, as in locomotive jib cranes and derricks, an addition may be made to the electro-magnetic brake in the form of a hand or foot release lever, by which the brake can be released or its pressure regulated. Loads are then hoisted by the motor, and are allowed to run down by their own weight, the speed of descent being regulated by the brake.

Where the driver operates the gear from a distance, the arrangement just described is not practicable, and some automatic or electrically controlled arrangement must be used to check the speed of descent of the load.



FIGS. 5,827 and 5,828.—Niles crane construction: Electric brake. It is of the ironclad solenoid type and is fitted with a removable brake band which engages almost the entire circumference of a turned and balanced wheel. The band is of special steel and lined with a renewable friction wearing surface. The brake is equally effective in either direction. The brake is always on when there is no current flowing through the motor and is always off when motor is running.

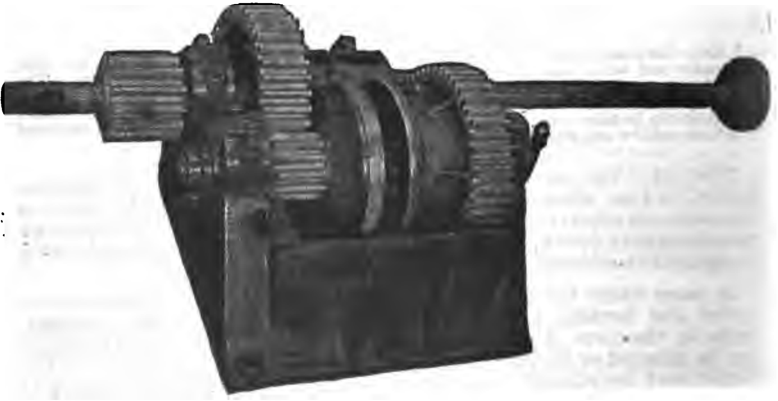
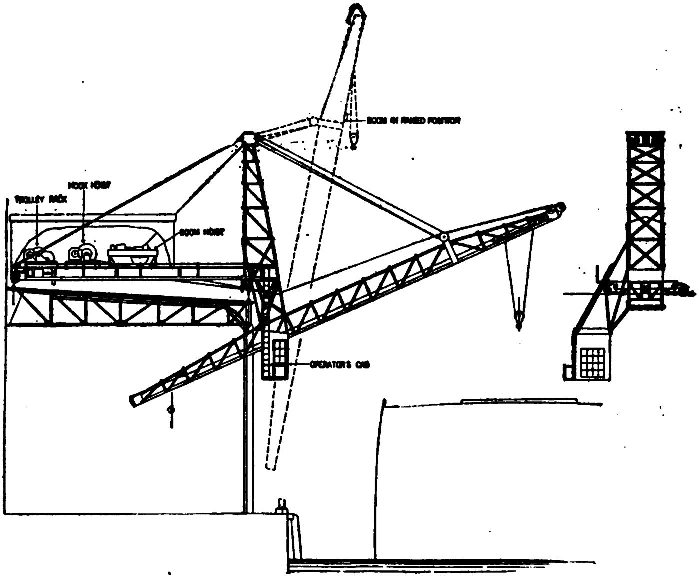


FIG. 5,829.—Niles crane construction: Mechanical load brake. It is of the double disc type with hard bronze wearing surfaces. It is automatic in action and self-contained, all thrusts being taken up within itself. The brake will not permit the load to run down unless the motor is revolved by power in the lowering direction. The brake, together with the intermediate steel gears, runs enclosed in a case, making a self-contained unit, insuring perfect accessibility, ideal lubrication and protection from dust and mechanical injury.

Automatic Mechanical Brake.—A common arrangement is the automatic mechanical brake. The brake is usually of the disc type, and is arranged to allow the gear to run freely in the direction of hoisting, but holds it from running in the opposite direction, being applied by a screw, or it can be arranged to be operated automatically by the load.



FIGS. 5,830 and 5,831.—Shaw overhead wharf crane. The handling of freight at a marine terminal presents two distinct but closely related problems: the loading and unloading of ships and the distribution of freight on the pier. The crane here shown is designed for such service and travels on tracks carried above the roof of the shed. The boom, when in working position, stands with the outer end extending over the ship and the inner end projecting through the doorway into the shed. The usual working angle is 24 to 30 degrees from the horizontal, but this angle can be varied as the height of the boat and other conditions may require. A trolley, comprising merely a light frame with the necessary pulleys and wheels, from which the hoisting block hangs, travels out and in from one end of the boom to the other. When the crane is not in service the boom can be raised to a nearly vertical position, in which position the lower end is withdrawn from the shed and the upper end is removed from over the ship. The shed doors can then be closed, the crane can be moved to another location, and ships can sail or dock without interference with the crane boom. This crane is adapted especially to those terminals in which a railroad track is extended along the edge of the pier. Having no supports outside of the railroad track, the space is clear, so that long material, such as poles, railroad rails and structural steel, can be handled between ships and cars without swiveling. The shed should have a height sufficient to give clearance for handling freight over the sides of the largest ships entering the port when floating light at high tide or river stage. A capacity of 6,000 pounds is considered suitable for most terminals, but this, as well as other details, can be varied to suit local conditions.

The brake is released by running the motor in the direction for lowering. As the motor releases the brake, the load tends to put it on again; consequently the speed of descent depends upon the speed of the motor, and this can, of course, be regulated by the driver by means of the controller.

Eddy Current Brake.—This type of brake is only used to a limited extent. It consists of a wheel, generally of copper or other metal of low electrical resistance, which is arranged to rotate between the poles of an electromagnet. The wheel is driven by the descending load, and eddy currents are generated in it, which give rise to a retarding torque. The eddy currents and the consequent torque are regulated by varying the strength of the magnet by means of a regulating switch and resistance.

Rheostatic Brake.—For this form of braking, the controller is provided with several positions on the lowering side, called *brake points*. In these positions the controller alters the connections of the motor to those of a series dynamo, so that it generates current when driven by the descending load, the energy being absorbed by the controller resistance. The speed of lowering is regulated by varying the resistance.

Regenerative Control.—Instead of a series motor, a shunt wound motor may be used to drive the hoisting motion. A shunt motor has the advantage that its speed can be efficiently regulated over a fairly wide range by inserting resistance in its field circuit. By this means considerable variation of speed in lifting and lowering may be obtained without the necessity of having variable speed gear in the hoisting train, and when lowering, the shunt motor, if overhauled by a load, becomes a dynamo and feeds current back to the circuit, thus automatically controlling the speed of lowering. This system has been in use to a limited extent for some years.

Collector Gear.—To convey current from the mains to the moving crane a collector gear, generally similar to that used for electric tramway work, is employed. For overhead cranes copper wires about one-quarter to three-eighths inches diameter are stretched along the gantry, being supported at the ends by globe strain insulators. Trolley wheels or slides, mounted on the end carriage, make contact with these wires.

From trolley wheels or slides, insulated cables are led to the switches and controllers, and to another set of trolley wires on the cross girders. Contact with these wires are made by sliders or trolley wheels on the crab, from which cables are led to the motors.

For locomotive jib cranes overhead or underground collector gear is used similar to that used for tramway cars. As derrick cranes only swing backwards and forwards through a portion of a circle, collector gear is not necessary. Connection from the supply mains to the moving part of the crane can be satisfactorily made by means of flexible armoured cable.

Controllers.—The class of controller most commonly used for crane work is that known as the drum, or tramway type. In these controllers the wires and cables are brought to a series of fixed contact, usually arranged in a straight line. A series of corresponding contact are attached to a revolving drum, the various combinations of connection for hoisting, lowering, etc., being obtained by rotating this drum into different positions.

Power Required to Drive Cranes.—The power required to drive the different parts of a crane is determined by allowing a certain friction percentage over the power required to move the dead load. On hoist motions 33⅓ per cent is allowed for friction of the moving parts, thus giving a motor one-third greater capacity than if friction were neglected.

For a bridge and trolley motions, a journal of friction of the track wheel axles of 10 per cent. of the total weight of the crane and load is allowed. There is then added an allowance of 33⅓ per cent. of the horse power required to drive the crane and load plus the track wheel axle friction to cover friction of the gearing.

Derricks.—By definition a derrick is *an apparatus for lifting and moving heavy weights*. It is similar to the crane, but differs from it in having the boom, which corresponds to the jib of the crane, pivoted at the lower end so that it may take different inclinations from the perpendicular.

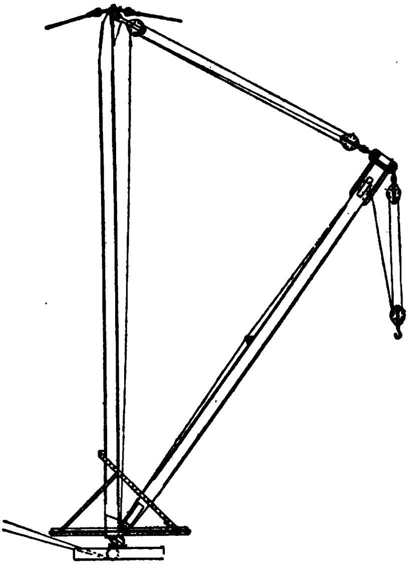


FIG. 5,832.—Terry standard guy derrick with bull wheel and swinging gear. ***In construction,*** all the fittings except the foot irons and sheaves are made of forgings or structural shapes. The foot block and mast slip are made with a ball and socket universal joint. Uneven setting or a settling of the derrick supports cannot make this joint pinch or retard the swinging of the boom. A back lock makes it impossible for the mast to be lifted clear of the step. The spider is made of buckeled plates. The regular set of iron for a guy derrick includes the mast head block, two sheaves in the foot block, one sheave in the mast step, and one sheave in the boom end.

The weight is suspended from the end of the boom by ropes or

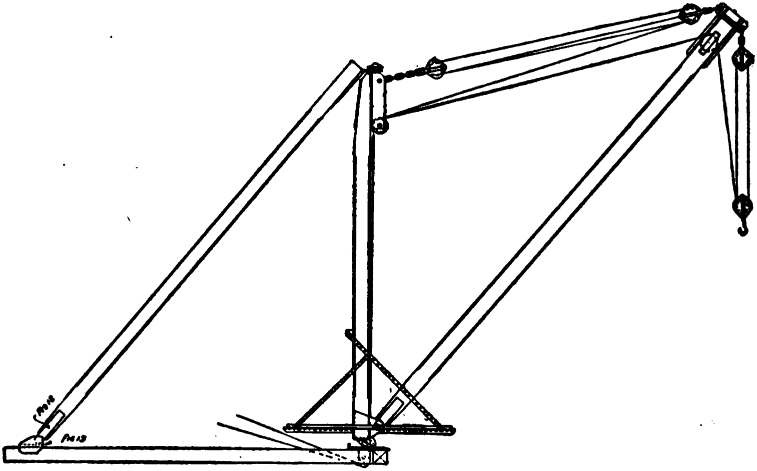
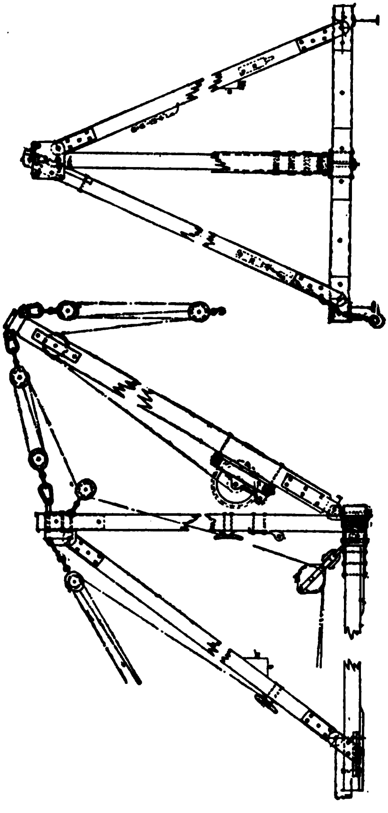


FIG. 5,833.—Terry standard stiff leg derrick with bull head and swinging gear. This type derrick has, as its name implies, rigid timbers or "legs" in place of guys. ***In construction,*** the goose neck irons for the stiff legs are made very heavy at the bend and bent close in to the mast top. The back or stiff leg connections to the sills allow the stiff legs to be set at any angle. They require no framing. When it is desired to rig these derricks with the fall line down the boom, one of the mast top sheaves is put in the mast step. The length of the boom should be approximately 1½ times the length of the mast.

NOTE.—***Power required for traveling cranes and hoists.*** Ulrich Peters, in *Machinery* November, 1907, develops a series of formulæ for the power required to hoist and to move trolleys on cranes. The following is a brief abstract. Resistance to be overdome in moving a trolley or crane bridge. P_1 = rolling friction of trolley wheels, P_2 = journal friction of wheels or axles, P_3 = inertia of trolley and load. P = sum of these resistances =

$$P_1+P_2+P_3=(T+L)\left(\frac{F_1+F_2d}{D}+\frac{V}{1{,}932t}\right)$$ in which T = weight of trolley, L = load, F_1 = coefficient of rolling friction, about .002 (.001 to .003 for cast iron on steel); F_2 = coefficient of journal friction, = .1 for starting and .01 for running, assuming a load on brasses of 1,000 to 3,000 pounds per square inch; (F_2 is more apt to be .05 unless the lubrication be perfect); d = diameter of journal; D = diameter of wheels; V = trolley speed in feet per minute; t = time in seconds in which the trolley under full load is required to come to the maximum speed. Horse power = sum of resistances × speed, feet per minute ÷ 33,000. Force required for hoisting and lowering: Fh = actual hoisting force, F° = theoretical force or pull, L = load, V = speed in feet per minute of the rope or chain, c = hoisting speed of the load L, c ÷ V = transmission ratio of the hoist, e = efficiency = Fh ÷ F°. The actual work to raise the load per minute = FhV = Lc = F°V ÷ e. The efficiency e is the product of the efficiencies of all the several parts of the hoisting mechanism, such as pulleys, windlass, gearing, etc. Methods of calculating these efficiencies, with examples, are given at length in the original paper by Mr. Peters.



FIGS. 5,834 and 5,835.—Terry "***Jinniwinks***" or so called "A" frame derrick. This differs from the ordinary stiff leg derrick in that it has in place of a boom, two inclined timbers, fastened to a horizontal cross piece and a stiff leg fastened to a second horizontal member projecting backward at right angles with the first. It is thus made with the minimum amount of framework, thus securing lightness with resulting ease of moving and erecting as well as security and rapidity of anchoring down.

chains that pass through a block at the end of the boom and thence directly to the *crab*, a winding apparatus or motor at the foot of the post. Another rope connects the top of the boom with a block at the top of the post, and thence passes to the motor below.

The motions of the derrick are:

1. A direct lift.

2. A circular motion around the axis of the post.

3. A radial motion within the circle described by the point of the boom.

On shipboard a derrick is a spar raised on end, with the head steadied by guys and the heel by lashings and having heavy weights. The accompanying illustrations show various types of derrick in general use.

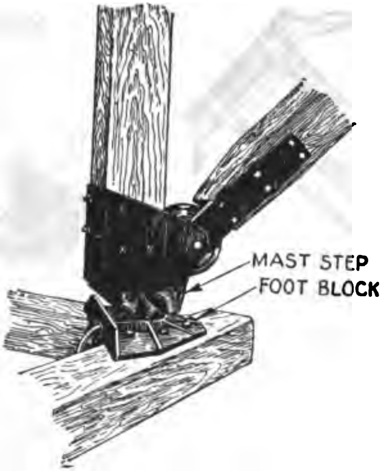
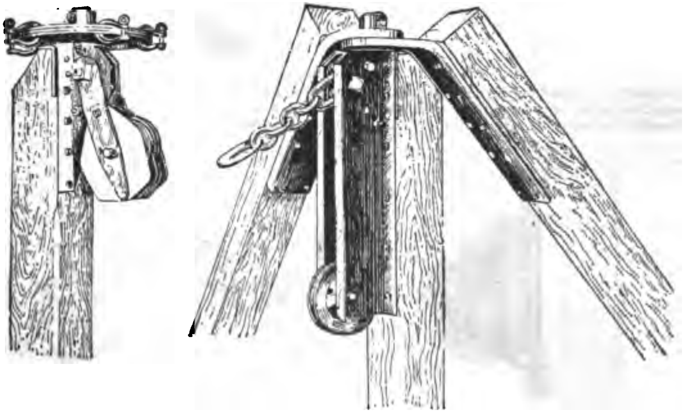
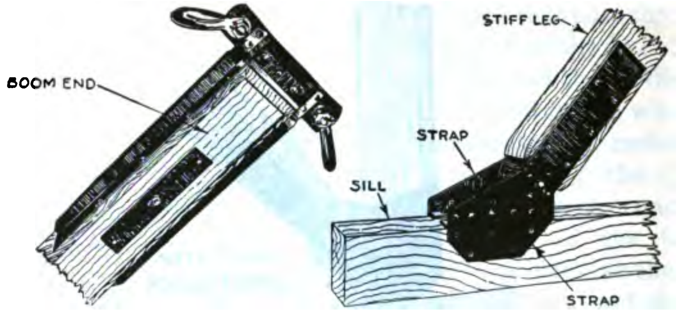


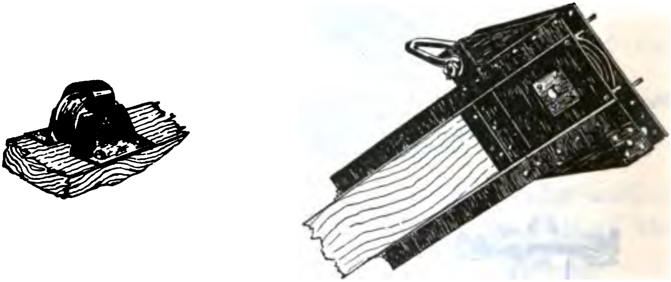
Fig. 5,836.—Derrick fittings: 1, *foot block and mast step irons*, showing lock at the rear of the ball and socket joint. There are two sheaves in the foot block and one in the mast step. The sheave in the mast step is not required for stiff leg derricks. Special foot blocks and mast steps are required for handling clam shell or orange peel buckets and other three line work.



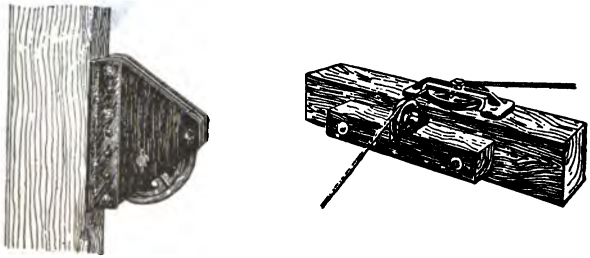
Figs. 5,837 and 5,838.—Derrick fittings: 2, *mast top irons*. Fig. 5,837, irons with spider plate for guy derricks; fig. 5,838, irons with goose necks for stiff leg derricks. Iron cone complete with block, pin, shackles, back plate and bolts as shown.



Figs. 5,839 and 5,840.—Derrick fittings: 3, *boom end* for general work and *stiff leg connection* to sill with stiff leg straps.



Figs. 5,841 and 5,842.—Derrick fittings: 4, *boom idler* for guy derricks and *boom end* for operating clam shell or orange peel buckets. The hole on lower side is for a shackle pin which can be used to attach upper block for a fall with several parts.



Figs. 5,843 and 5,844.—Derrick fittings: 5, *mast brackets* used with derricks operating clam shell and orange peel buckets, and *guide sheaves* for bull wheel line.

Hoists.—For lifting heavy pieces in machine shops and various other industrial plants, various forms of hoist are used. These may be classified

1. With respect to the power employed, as

   a. Hand.
   b. Pneumatic.
   c. Electric, etc.

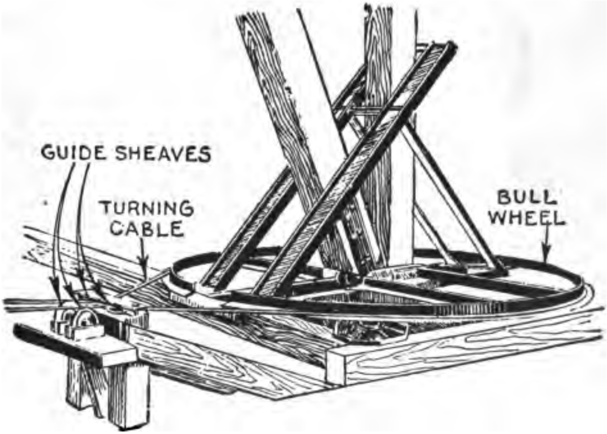


FIG. 5,845.—Derrick fittings: 6, Terry all steel bull wheel and guide sheaves. The wheel is made in halves and may be conveniently erected without unstepping the mast. The ring is a heavy angle iron with the vertical leg rolled with an appreciable outward flare which eliminates any tendency for the line to climb. An inverted movable section of the ring is placed under the boom which makes it a full circle. The braces which drive the boom are made of steel beams, and sills of heavy angles.

2. With respect to the lifting medium, as

   a. Rope.
   b. Chain.

3. With respect to the form of gearing, as

   a. Pulley (block and fall).
   b. Differential.
   c. Spur geared.
   d. Differential.
   e. Worm.

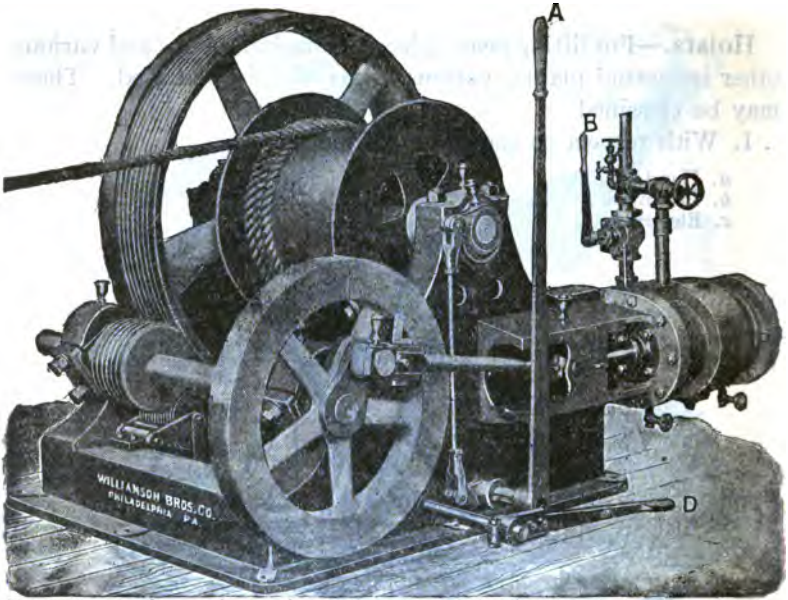


FIG. 5,846.—Williamson single cylinder, single drum frictional geared winch with overhauling gear. A governor attachment is provided so arranged as to be wide open when the lever is in position for hoisting. This attachment is closed when the lever is thrown back on the brake, holding the load, and has sufficient lap to remain closed when the lever is in the neutral position or has eased up on the brake for lowering. A starting or pass over valve is used for giving steam to keep the winch running when the governor valve is closed, so that sufficient speed can always be maintained to prevent stopping on the center. The winch is started with the pass over valve and then the lever B, operating the stop valve, is opened far enough to take care of the load to be lifted and the speed required. Moving the lever A, over, throwing the gearing into mesh and opening the governor valve, all the steam which passes through the stop valve is allowed to enter the cylinder and the load is thus raised at the speed corresponding with the opening of the stop valve B. When the load reaches the required position, the lever is thrown back and the governor valve, by shutting off the steam, slows down the engine. Then, by easing up on the lever, the brake allows the load to be lowered at any speed desired, the engine meanwhile running ahead slowly to avoid dead centers. In uniform hoisting, after the lever B, has been set to suit the load and speed, it is unnecessary to handle any lever except A, for the operation of hoisting, stopping and lowering. ***In fast hoisting,*** however, even though the load and the speed desired be uniform, it is advisable to regulate with the lever B, in such way as to start slowly until the load is clear, then open up for fast speed and slow down again before throwing on the brake. The overhauling attachment is auxiliary to the ordinary working, and is used only to aid in reversing or overhauling the drum of the larger sized winches. With the smaller winches, this attachment is not necessary, as the engineer can easily start the drum back by a push on the drum or a pull on the rope. The drums of the large winches are so situated that the engineer has no chance to pull the rope, and the heavy drum requires considerable effort to start it backward. For this reason, this device is fitted. With the lever A, in the central position for lowering, the overhauling attachment is operated by a foot lever D. The pressure of the engineer's foot on lever D, brings the overhauling gear into contact and reverses the drum. Removal of the pressure from lever D, throws the overhauling gear out of contact and leaves the machine in the same condition as one not fitted with this attachment.

The hand operated types in general use are known as block and fall, and chain hoists. The common types of power operated hoists are driven either by an electric motor or a pneumatic motor.

In the operation of the so called air hoists, the load is lifted by the direct application of air pressure in a cylinder containing a piston that is attached to the lifting member of the hoist.

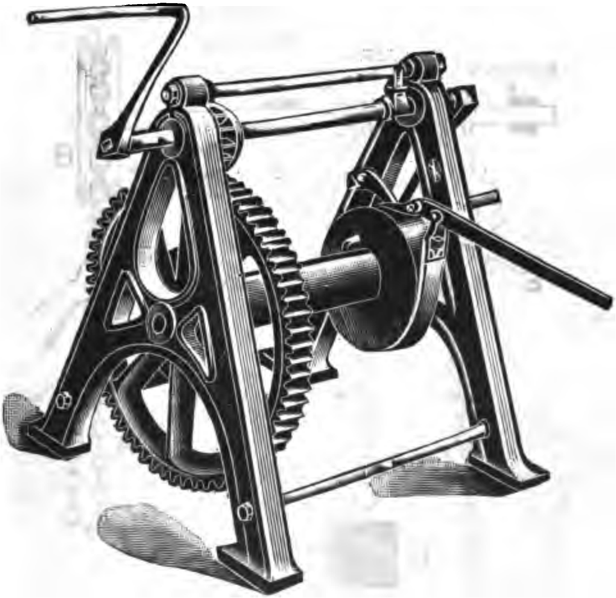


FIG. 5,847.—Crab winch, or hand windlass. The machine shown is fitted with a brake for lowering; a latch, seen near the further frame, holds the pinion or crank shaft in gear. When desiring to lower, the load is held on the brake, the latch lifted, pinion shaft thrust to the right out of gear and locked, the load being lowered on the brake without the handles revolving. When using a winch of this description for wire rope, the barrel or drum should be at least twenty times the diameter of the rope; this is to prevent the individual wires being broken by passing through too sharp an angle.

The worm hoist shown in fig. 5,848, although less efficient than a properly designed block of the spur gear type, has the advantage of lower first cost, and of very smooth action, both in hoisting and in lowering.

The differential hoist, whose principle is shown in figs. 5,849 and 5,850, was invented in 1854 by Thomas A. Weston. It is comparatively inexpensive and very simple in construction.

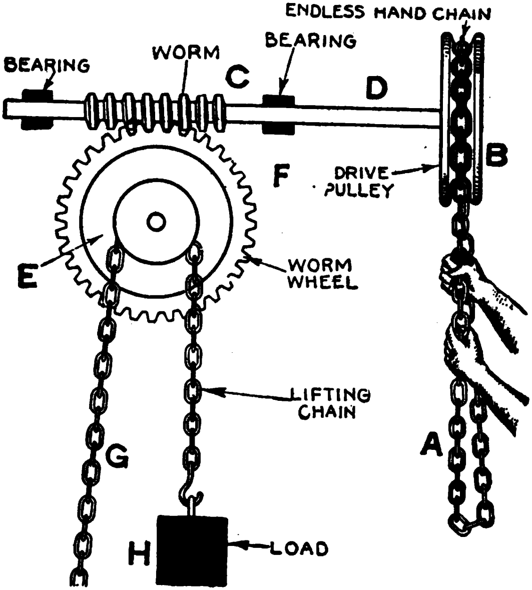
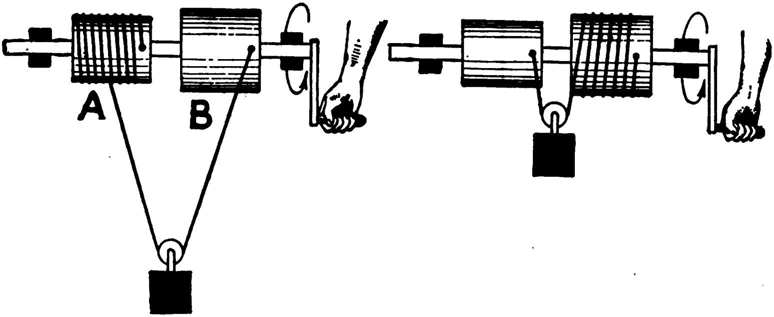


FIG. 5,848.—Elementary worm gear hoist. The hand chain A, is used for rotating the drive pulley B, which is connected to the worm by a shaft. The worm meshes with the worm wheel E, whose shaft is attached to the pulley F, over which passes the lifting chain G. The pulley F, has pockets for receiving the chain links so that the chain cannot slip inlifting the load H.

There are three kinds of air hoist:

1. Single acting.
2. Balanced.
3. Double acting.

These consist essentially of a cylinder, piston, piston rod through which the lifting force is transmitted to the load, and control mechanism. In the single acting type, as shown in figs. 5,852 and 5,853, compressed air



FIGS. 5,849 and 5,850.—Chinese windlass illustrating the principle of the differential hoist. ***It consists of*** two drums, A, and B, (one a little larger than the other) connected to a shaft and having the ends of a lifting cable attached to the drum as shown, so that in turning the crank the cable will simultaneously unwind on one drum and wind on the other. Fig. 5,849 shows the beginning of the lifting operation. As the crank is turned clockwise the cable winds on B, and unwinds on A, and since B, is larger in diameter, the length of cable between the two drums and load is gradually taken up, thus lifting the load. Evidently by making the difference in diameter of the two drums very small an extremely large leverage is obtained thus enabling very heavy weights to be lifted with little effort. The load will remain suspended at any point, ***because the difference in the diameter of the two drums is too small to overbalance the friction of the parts.*** Fig. 4,850 shows the end of the lifting operation.

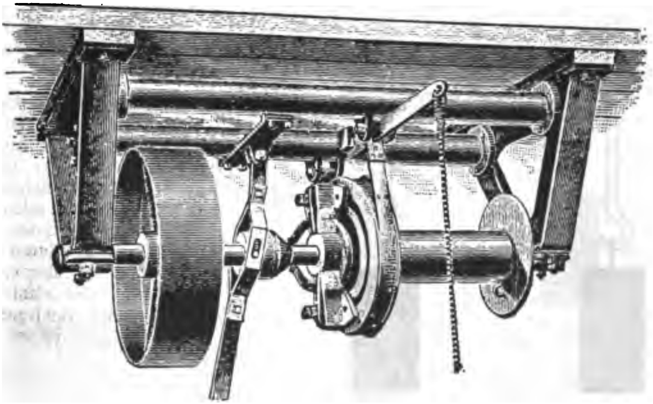
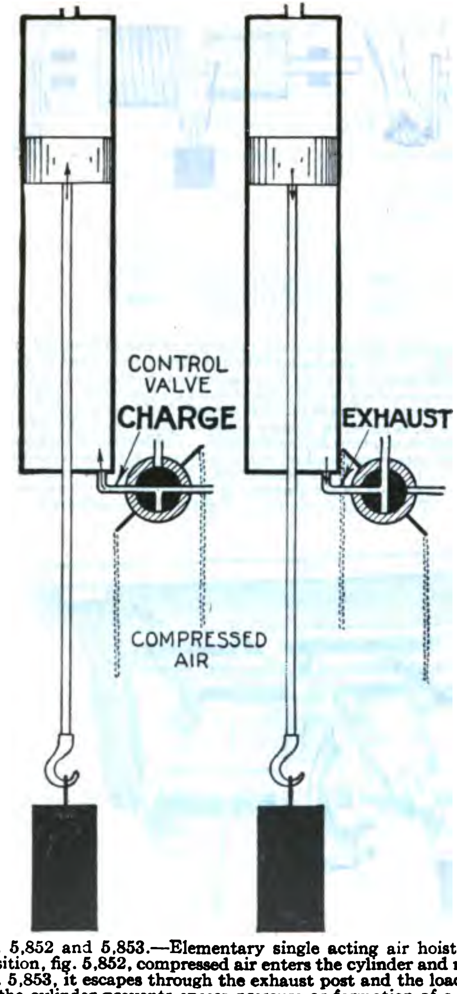


FIG. 5,851.—Eastern single shaft friction hoisting machine (capacity 750 lbs., direct pull). ***It consists of*** a single shaft supported in a substantial iron frame. On this shaft is the driving pulley and a loose drum driven with an improved friction clutch, a band brake being provided around the drum head for holding the load at any point. These machines are usually arranged to hang on a ceiling but may be made to stand on the floor. Driving pulley is 24 inches diameter by 6 inches face. Drum is 6 inches diameter by 16 inches long inside flanges. The iron frame occupies a space 5 feet long by 3 feet wide.

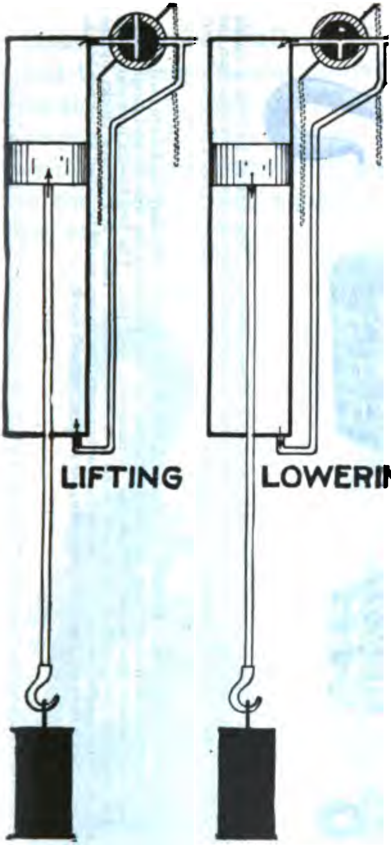


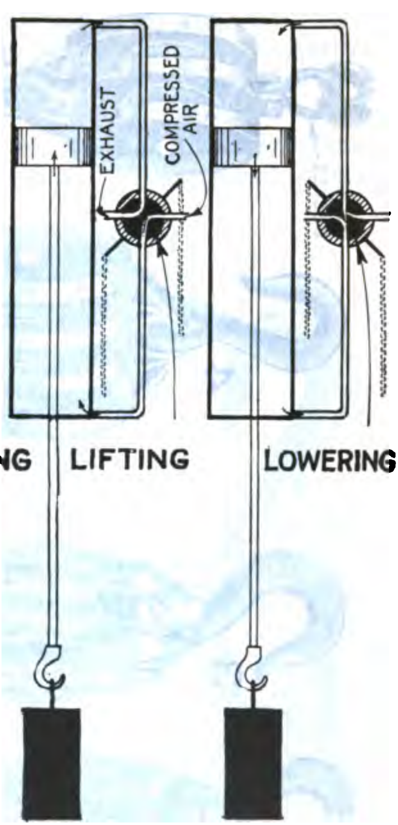
is admitted to the stuffing box side of the piston only, and, when lowering the hoist this air is exhausted. During the exhaust stroke an opening to atmosphere prevents a partial vacuum forming on the other side of the piston.

The balanced type of air hoist, shown in figs. 5,854 and 5,855, is so arranged that there is full air pressure on the stuffing box side of the piston at all times. The load is hoisted by exhausting air from the space above the piston, and is lowered by admitting air above the piston, the unbalanced area due to the space occupied by the piston rod aids in forcing the piston downward. The advantage of such arrangement is accuracy of control.

In the double acting air hoist, as shown in figs. 5,856 and 5,857, air may be admitted to or exhausted from either side of the piston, admission and exhaust occurring simultaneously from opposite sides of the piston, adapting the hoist to service where both pushing and pulling effects are desired.

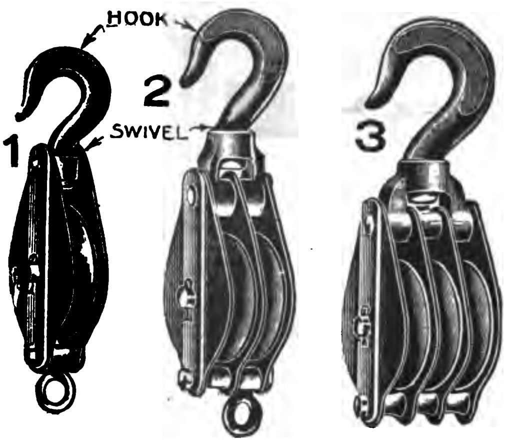
Figs. 5,852 and 5,853.—**Elementary single acting air hoist.** When the control valve is in position, fig. 5,852, compressed air enters the cylinder and raises the load; when in position, fig. 5,853, it escapes through the exhaust post and the load descends. The vent in the top of the cylinder prevents excess pressure or formation of a vacuum in the upper end of the cylinder due to movements of the piston. The speed at which the load is raised or lowered will evidently depend upon the degree of opening of the control valve. These hoists are frequently attached to jib cranes and overhead trolleys as well as for use in lifting castings and forgings around machine tools.



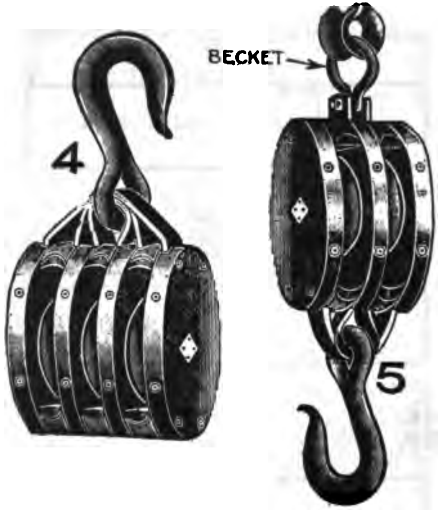


Figs. 5,854 and 5,855.—Elementary balanced air hoist. ***In operation,*** compressed air at full pressure is at all times admitted to the lower end of the cylinder. When the control valve is in position, fig. 5,854, air is exhausted from the upper end and the excess pressure on the lower side of the piston raises the load. When the valve is tuned to position, fig. 5,855, the pressure is equalized on both sides the piston, but the effective area on the upper side is slightly greater than on the lower side because of the area rendered inactive by the piston rod, hence the force or ***total*** pressure tending to push the piston downward is greater than that tending to push it up and the load descends.

Figs. 5,856 and 5,857.—Elementary double acting hoist. ***In operation,*** when the control valve is in lifting position, fig. 5,856, compressed air enters the lower end of the cylinder and exhausts from the upper end; when in the lowering position, fig. 5,857, the opposite air distribution obtains as clearly shown.



FIGS. 5,858 to 5,860.—Iron sheave blocks. **1,** single sheave; **2,** double sheave; **3,** three sheave. These united to form a tackle similar to fig. 5,866, are used for handling weights by manual power, the lower block generally having one sheave less than the upper. The standing end of the rope is seized to the *becket** of the lower block, *rove* first through the upper, then the lower, and so on until the fall finally depends from the upper.

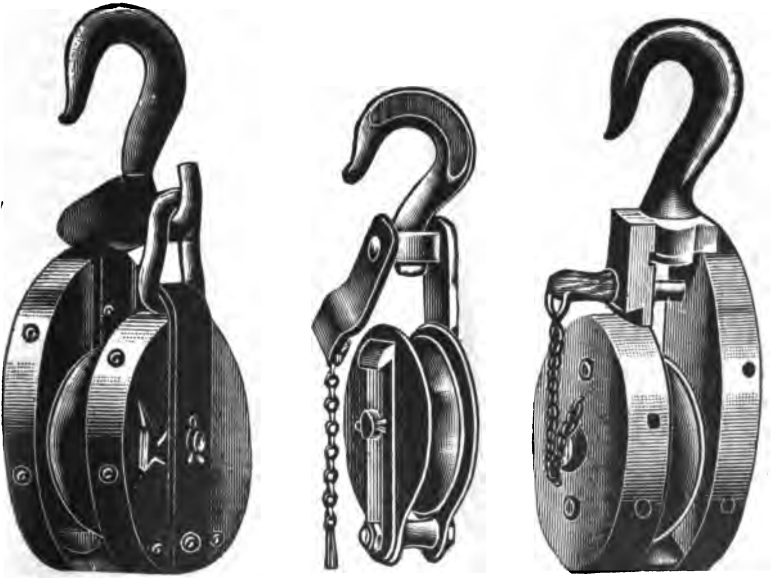


FIGS. 5,861 and 5,862.—Wooden blocks. Fig. 5,861, **4,** three sheave; fig. 5,862, **5,** two sheave. Wooden blocks are used out of doors in preference to iron ones, in connection with derricks, gin poles or rigging, as they will stand the weather and rough usage better. The sheaves are of brass or of lignum vitae bushed with bronze, working on a steel pin. The two blocks here shown are commonly united by rope, the assembly being called "*block and tackle*" or briefly *tackle*. Some denominate blocks by the number of times the rope or *block fall* passes the lower pulleys, hence the combination here shown would be called a four run block. The mechanical gain is five fold. Since *there are five ropes supporting the lower or movable block.*

---

*NOTE.—***Becket;*** by definition, a loop at the lower end of a block to which the standing part of the fall is made fast.

Combination of Pulleys.—For lifting heavy weights recourse is had to the mechanical power known as *the pulley*, consisting in its simplest form of a grooved wheel rotating on an axis. The mere passing of a rope over one fixed pulley for hoisting a weight does not give any increase of power, the force necessary to sustain the weight being equal to the latter, plus friction of the rope, etc.



Figs. 5,863 to 5,865.—Snatch blocks. Pulley blocks have frequently to be used as fair leads or guide pulleys, for a block fall to a winch or capstan, when the pull is not in a straight line; and in that connection it is very inconvenient to have to reeve or unreeve a long rope through the sheave. To save this trouble, part of one cheek of the block is made to work on a hinge or joint, forming a *snatch block*, three types of which are here shown. Fig. 5,863 is locked by a link and bent pin, which latter is turned around to release the latch. A common iron snatch block is shown in fig. 5,864, the cheek swinging clear to get the rope in or out, locking on a wedge and fastened by a split pin. The usual type on shipboard has the movable part working on a hinge, and locking by means of a forelock or cotter thrust through a pin protruding from the fixed part through a hole in the latched portion. Fig. 5,865 shows what is known as the burr pattern, the hinge being locked by means of a wooden pin.

The gain consists altogether in more convenient application of the power exerted, as it is easier to haul downward on a pull of 100 lbs. than to lift 100 lbs. directly from the ground. This may be termed *mechanical advantage* as apart from *multiplication of power*.

When, however, one end of the rope is fixed, passes *under* the single pulley to which the weight is attached, and the free end is lifted, the travel of the rope or cord is double that of the weight, and the power necessary to sustain the latter is half the weight plus friction. It may be stated in the reversed proposition, that with a *movable pulley* the weight capable of being lifted is *twice the force applied* minus the friction of the apparatus.

Combinations of pulleys are arranged with several sheaves in one case, to form a block to secure this multiplication of power. The upper or fixed block gives the mechanical advantage of application, and the lower or movable block, by multiplying the travel of the rope as compared with

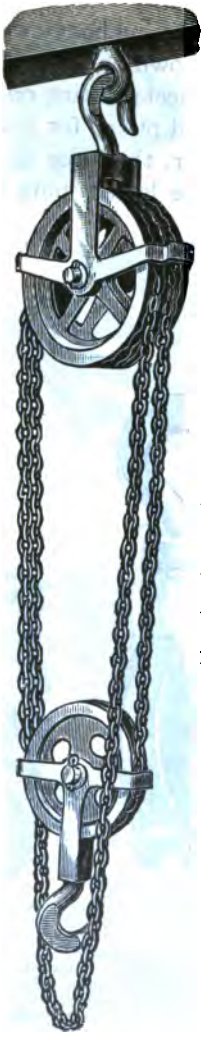


FIG. 5,867.—Differential hoist. It depends for its utility upon giving a very slow travel of the weight in comparison with the speed of the haul. This is secured by making the two upper pulleys of nearly the same size, the endless chain being *paid out* by one while it is *hove in* by the other. ***In other words,*** the smaller sheave tends to lower the weight while the larger one raises it, the total lift equaling the difference of circumference of the two sheaves. Assuming in this case that there are 25 sprocket teeth in the larger sheave and 23 in the smaller, the velocity of haul as compared with that of the lift will be $\frac{2\times25}{25-23}$ or 25 to 1 consequently a pull of 80 lbs. will lift 1 ton of 2,000 lbs. This style of block is fitted with an endless chain, which obviates a serious objection to the principle of the differential windlass, namely, the great length of rope required if the displacement of the object moved is to be very large.

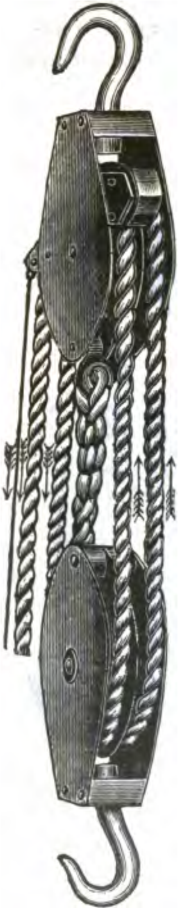


FIG. 5,866.—Block and tackle. The arrows show the direction of travel of the rope.

that of the weight, increases the power in proportionate ratio. Each movable pulley halving the power necessary, with two sheaves the force necessary is one-half of one-half, or one-quarter. Briefly, the weight capable of being lifted is equal to *the force multiplied by the number of ropes supporting the lower or movable block*.

Examination of the block and tackle shown in fig. 5,866 will make this clear, the arrow heads showing the direction of travel of the rope, or *fall*,

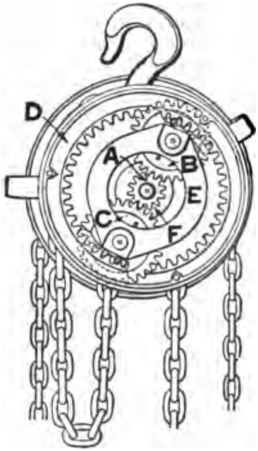


FIG. 5,868.—Planetary Spur geared "Triplex" block or hoist. The power is transmitted from the hand chain to the load chain. ***In operation***, when the hand wheel carrying the hand chain is rotated the pinion A, is also rotated and transmits its motion through two intermediate gears B and C, at two points always diametrically opposite each other. Pinions fixed to gears B and C, engage an internal gear D, which acts as a fulcrum and causes the pinion case E, to revolve. This pinion case is keyed to the sheave F, which carries the load chain of the hoist. The load is held at any given point and the hoist prevented lowering until the hand wheel is turned in the opposite direction, by a friction brake and ratchet mechanism. Motion from the hand wheel is transmitted through friction discs to a hub which drives the pinion A. The hand wheel is screwed onto a threaded extension of the hub, and interposed between these two parts is a ratchet disc. These discs, one of leather and the other of galvanized iron, are placed in contact with the sides of the ratchet disc, and the different pinions referred to are so arranged that, when the hand wheel is rotated in the direction for hoisting, it is screwed onto the hub, hence the ratchet disc is gripped between the hand wheel and hub so that all the parts rotate together and motion is transmitted to the driving pinion A. Whenever the downward pull on the hand chain is discontinued, the load is prevented lowering by a pawl which engages the ratchet disc. When it is desired to lower the load, the hand wheel is pulled around in the opposite direction, which unscrews it somewhat, thus releasing the friction mechanism, which permits the hub to revolve, as the result of the force of the sustained load which is transmitted through the system of gearing and causes pinion A, to rotate. This rotating of the pinion and the hub on which the hand wheel is screwed causes the hub to tighten quickly, provided the rotary movement for lowering is discontinued. There is a continuous slippage between the friction surfaces as long as the hand wheel is rotated in the reverse direction. As soon as this rotation is stopped, the downward movement of the load is stopped.

as it is termed. The thin cord shown manipulates a patent brake, seen in the upper block, which locks the rope should it be desired to suspend the object lifted.

It will be evident, upon consideration, that no two sheaves travel at the same velocity, on account of the varying speed of the different parts of the rope. *It is therefore requisite that the sheaves be independent of each other*, revolving loosely upon a spindle fixed in the shell or frame of the block.

A basal factor of all mechanical powers is, that *whatever is lost in time is gained in power*, or the reverse. It has been seen that with the weight traveling half as fast as the rope, double the weight could be lifted with the same force, or a force of only half the weight was necessary.

Northern Standard Hoists

(Sizes, speed and lifts, type D)

Frame No.	Capacity in Pounds	HOISTING SPEEDS Feet per minute	
		Direct Current	Alternating Current
B¼	500	20 to 40	20 to 22
B½	1,000	10 to 20	10 to 11
F½	1,000	25 to 50	25 to 27
B1	2,000	5 to 10	5 to 6
F1	2,000	20 to 50	20 to 22
F1½	3,000	15 to 40	15 to 16
F2	4,000	10 to 25	10 to 11
G2	4,000	20 to 40	20 to 22
G3	6,000	17 to 40	17 to 18
G5	10,000	9 to 20	9 to 10
G6	12,000	8 to 20	8 to 9
G8	16,000	9 to 20	9 to 10
G10	20,000	8 to 20	8 to 9

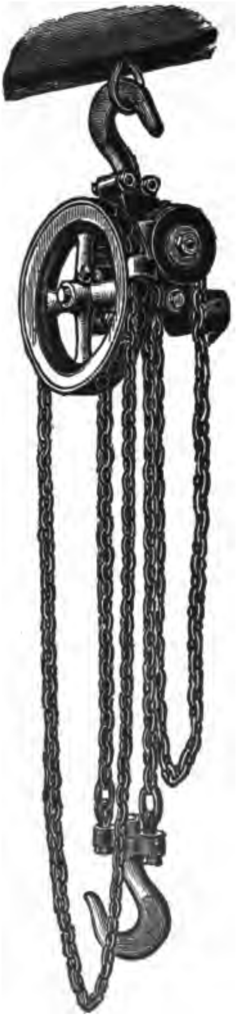
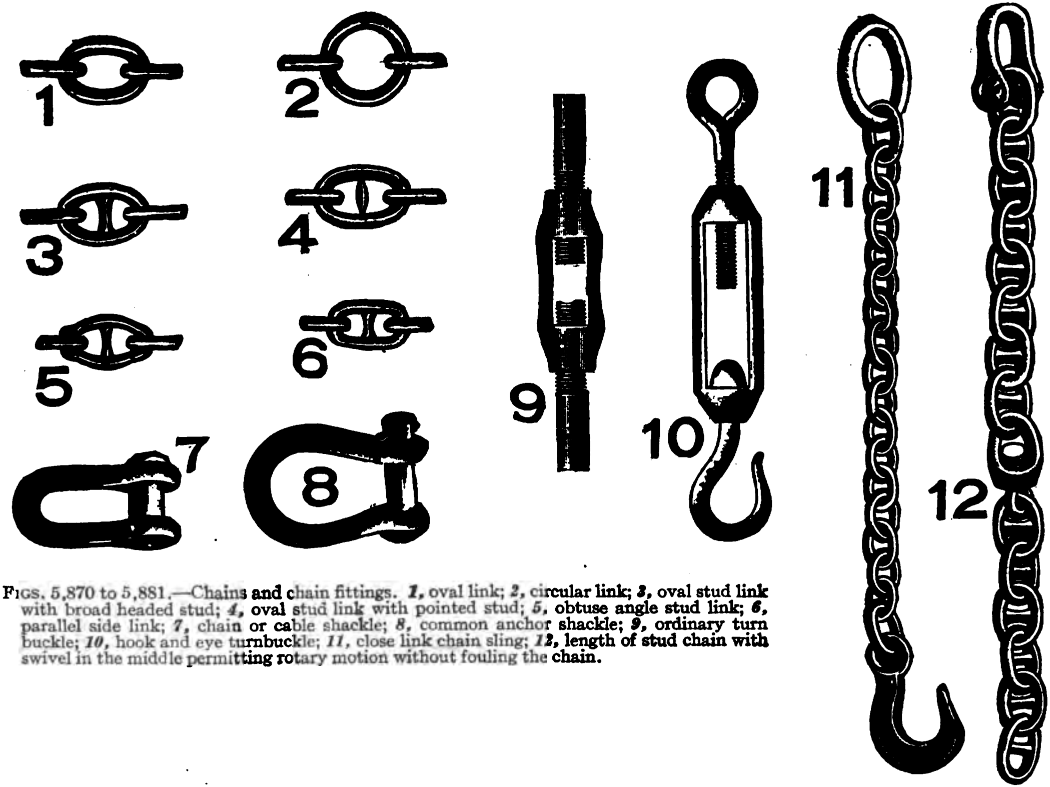


FIG. 5,869.—Worm gear hoist. ***In operation***, an endless chain, passing around a sprocket or ***gipsy wheel***, rotates a worm, and, by multiplying gearing, hauls on the lifting chain. In the illustration this will be seen to be double, for giving a steady lift, and it is raised or lowered by the small gipsy wheels seen to the right. Not only is the gain of power, at the expense of time, obtained by the multiple gearing of this device, but the ***worm prevents slipping***, and as there is no weight on the hand chain ***a jam is not dangerous***.

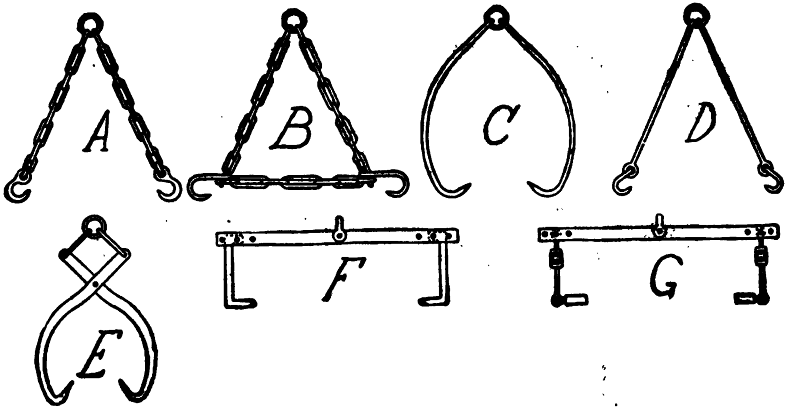


FIGS. 5,870 to 5,881.—Chains and chain fittings. *1*, oval link; *2*, circular link; *3*, oval stud link with broad headed stud; *4*, oval stud link with pointed stud; *5*, obtuse angle stud link; *6*, parallel side link; *7*, chain or cable shackle; *8*, common anchor shackle; *9*, ordinary turn buckle; *10*, hook and eye turnbuckle; *11*, close link chain sling; *12*, length of stud chain with swivel in the middle permitting rotary motion without fouling the chain.

Chains.—These are made of round bar iron or steel forged into links, by bending to shape and welding.

The stud is a distance piece, usually of cast steel, which serves to strengthen the link; it is used on the larger sizes alone and permits a longer link. Most chains for heavy stresses are made this way.

Fig. 5,880 shows a close link chain sling, having a large open circular link in which the hook engages. A length of stud chain is illustrated in fig. 5,881, and is noteworthy on account of the swivel in the middle of its length, permitting rotary motion without fouling the chain.



Figs. 5,882 to 5,888.—Various slings and tongs or grapples, showing types most frequently used. The number of chains, number and shape of hooks, etc., may be varied to meet conditions.

Turnbuckles are generally used to strain both chains and ropes taut, fig. 5,879 being what is termed a hook and eye turnbuckle adapted for tightening the shrouds or guys of a flagstaff post or derrick. Fig. 5,878 is an ordinary type of turnbuckle, sometimes known as a stretching screw, provided with right and left hand threads to tauten stays, etc.

A chain or cable shackle as seen in fig. 5,886, is used for connecting lengths, usually 15 fathoms, of a cable; the bolt has a countersunk head and is locked by a wooden or brass taper pin, as iron would rust in. Fig. 5,877 (*8*) represents the common anchor shackle, in which the pin is attached by a cotter or fore lock; this type is occasionally termed *clevis*.

Chains, both stud and close link, should be obtained from reliable sources. In view of possible deterioration and the severe strains to which they are subjected, crane chain slings, etc., should not be worked above a safe load.

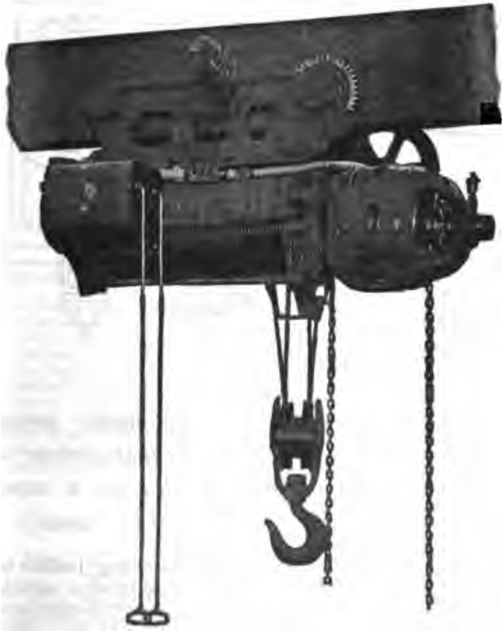
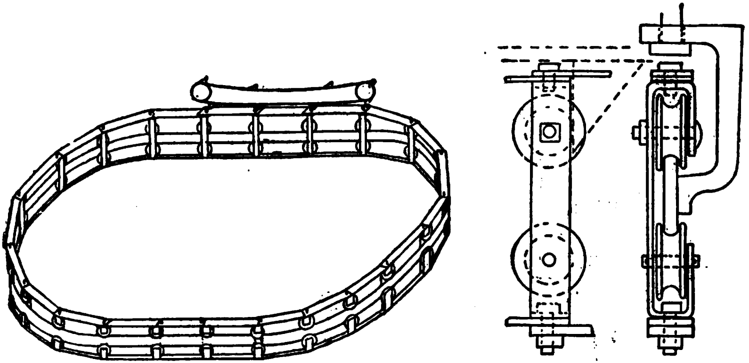


FIG. 5,889.—Northern *floor* controlled electric two motor trolley hoist. It is adapted to the more heavy and continuous service of foundry, iron, steel and other industrial plants requiring unusual speeds, control and lifts. This is a very heavy hoist for severe duties. It is generally furnished combined with the trolley. It can be modified as to lifts, speeds and motor sizes and can be readily adapted to a wide range of duties. This hoist is made in both one and two motor forms —floor or cab controlled. All hoist gears run enclosed in oil and have bronze bearings. Both automatic mechanical (or dynamic) brakes in combination with motor brakes are furnished. A limit stop for hook is provided.

Crane chains require to be taken off twice a year and annealed; that is, placed in a muffle or reverberatory furnace, brought slowly to a red heat, and cooled off gradually, covered the while with ashes or sand to exclude the air. This process is rendered necessary on account of the crystallization or alteration of fibre set up in the metal by the constant jar and reversal of strain. Broken crane chains often exhibit a granular fracture like cast iron.

Running chains should be lubricated with blacklead (graphite) mixed with tallow, and care should be taken to arrange all leads so that no "nips" should occur, as these are very destructive and shorten the life of the chain considerably.

A supply of split or patent links for each size of chain in use should be kept by the storekeeper of the erecting gang, as much time is lost in binding the two ends of a broken chain together with wire. Shackles of course can be used for the larger sizes in cases of need.



FIGS. 5,890 to 5,892.—Delta continuous trolley system.

Telpherage.—This word is defined as: *Automatic aerial transportation as by the aid of electricity, especially that system in which carriages having independent motors are run on a stout wire conducting an electric current.*

Telpherage is a name introduced by the late Professor Fleeming Jenkin to designate a system devised by him, by which the transmission of a vehicle by electricity to a distance is effected independently of any control exercised from the vehicle; it is an aerial electrical railway.

Telpherage properly includes those systems employing a wire or cable for a track, but the term is erroneously applied to systems using a rail. There are two divisions of telphers.

1. Automatic.
2. Non-automatic.

Ques. What are automatic telphers?

Ans. Those which are driven by electric motors, the control being a part, or remote from the telpher. The original telphers were automatic, the telpher being placed in the middle of the train.

Ques. What is the chief use of automatic telphers?

Ans. They are employed for handling coal, ore, and bulk material.

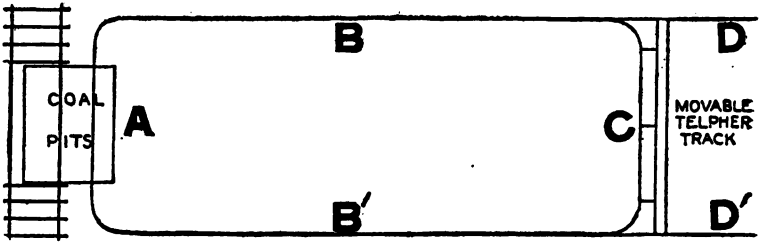


FIG. 5,893.—Typical arrangement of mono-rail tracks. The track is supported on brackets attached to buildings, or is supported on A bents. Supports under straight track are spaced 20 feet apart, and on curves, the spacing is 8 feet. For long spans, cables or trusses are used. The tracks may be either fixed or movable. *In the figure,* the side tracks BB′, are fixed, but C, is movable, being attached to a traveling bridge. The speed of this bridge is from 300 ft. to 900 ft. per min. The motor driving this bridge would have a load factor of .16. The telpher train is passed from these side tracks B′, by means of a gliding switch upon the movable track C. This track therefore may be placed anywhere over the area between the fixed side tracks. The telpher returns by means of the track B′, to its starting point A. By the operation of this movable track all the space can be served; this operation is called transferage. The minimum allowable radius of curves is 8 ft.

Ques. Define non-automatic telphers.

Ans. Non-automatic telphers are those which are controlled by an operator who travels with the load and who operates both the telpher and hoists from a cab or case which is attached to the telpher or carriage.

Non-automatic telphers are employed for bulk material, like the automatic telpher, and are also used for the hoisting and conveying of miscellaneous material, boxes, cases and barrels, the package freight of railways and the mixed cargoes of steamships.

Ques. How is a telpher suspended, and driven?

Ans. From one or more wheels in tandem, of which one or all are driven by the electric motor or motors.

In the minimum head room two ton type designed for railway and steamship terminals the vertical space from the underside of the roof girders to the bottom of the hoist hook is 4 ft. 9 in. (144.8 cm.). The width of the hoist is 3 ft. 3 in., and 4 ft. 8 in. to the limit line for 10 degrees swing. From the center of the rail to the inner limit of the telpher and hoist is 16 inches.

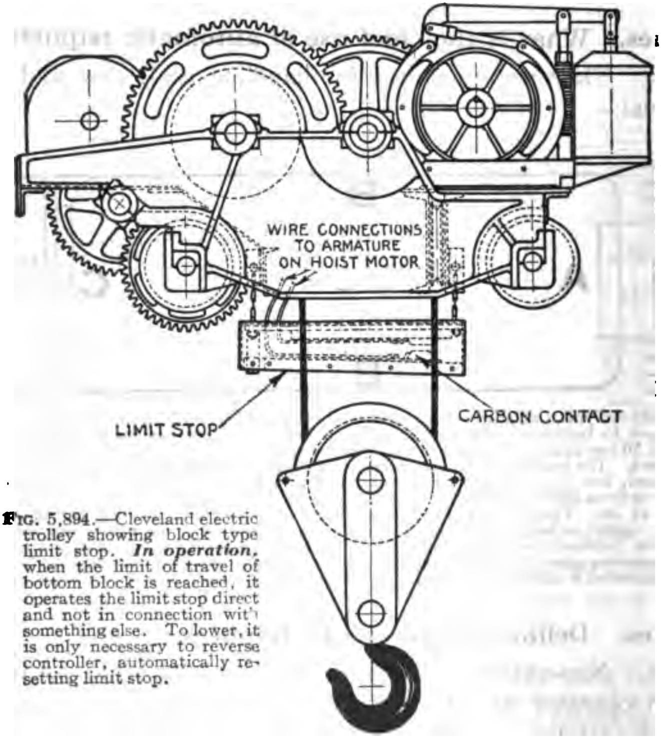
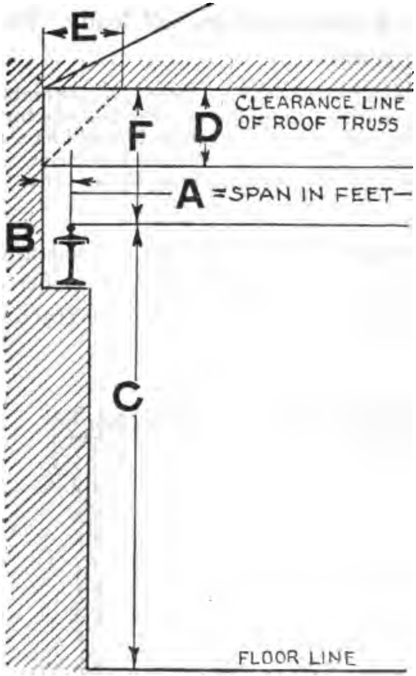


FIG. 5,894.—Cleveland electric trolley showing block type limit stop. *In operation,* when the limit of travel of bottom block is reached, it operates the limit stop direct and not in connection with something else. To lower, it is only necessary to reverse controller, automatically re-setting limit stop.

Ques. Describe the power features.



Ans. Energy in the form of either direct or alternating current is communicated to the motors by conductors which lie parallel to the track, the contact being made by shoes or wheels. Sometimes storage batteries suspended from the telpher or the carriage are employed. On steep grades the telpherage traction, in some installations, has been assisted by supplementary cables, either fixed or movable.

FIG. 5,895.—Section of shop showing information required in selecting a crane. ***Load,*** maximum in net tons; ***speed,*** if special for any function be preferred; ***style,*** outside or inside service; ***current data,*** whether *d. c.* or *a. c.*, giving voltage cycle and phase; ***clearance dimensions,*** A, span; B, end clearance; C, distance from top of runway rail to floor; F, overhead clearance; E and F, roof braces if any that would interfere with end travel of trolley.

Telpher Motors.—The sizes of motor for telphers and hoists will depend upon the class of work to be done; the motors for telpher tractors vary from 5 to 15 *h.p.* and for the hoists, from 3 to 75 *h.p.*, the loads being from 500 lb. to 30,000 lb. The load factor for the tractor motor is .25 and for the hoisting motor .16. The driving wheels and the motors may be connected by gears or by chain drive. The maximum service efficiency of the motors is that corresponding to the efficiency obtained between one half and three-quarters full load. The motors are of slow or medium speed.

Direct current 250 volt or, 500 volt series wound motors are preferable for tractors and hoists though alternating current motors afford satisfactory results. The motors should be dust and weather proof, and should have a 50 per cent. reserve in their rating. The average combined efficiency of the motors and gearing, for the tractor and hoist, is from 65 per cent. to 75 per cent.

Brakes.—The mechanical type of telpher brake is used and the hoist brake is of either the electro-mechanical or electro-dynamic types. Spur gears and chain drive on the tractor transmit the power from motor to track wheels, and either spur or worm gear is used to transmit power to the hoisting drum.

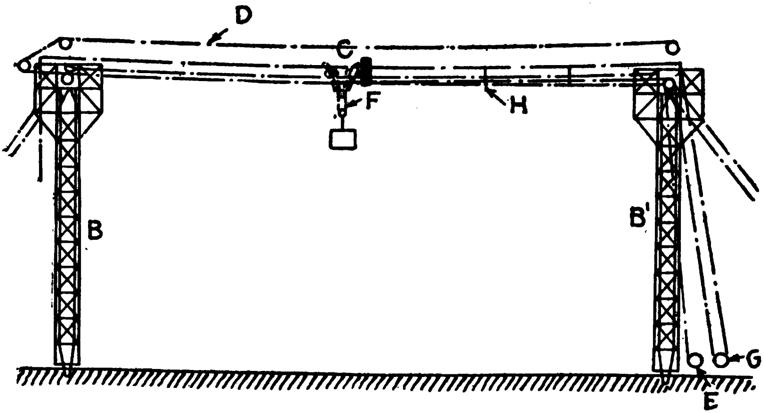


FIG. 5,896.—Cableway. The essential elements of construction are BB', towers; C, cable; D, hauling rope; E, hauling rope drum; F, hoisting rope; G, hoisting drum; H, hoisting rope slack carriers.

Trackage.—Telphers either run in one direction on a closed track circuit, or to and fro over a single line. On the single line the automatic telphers reverse themselves on completing their trips.

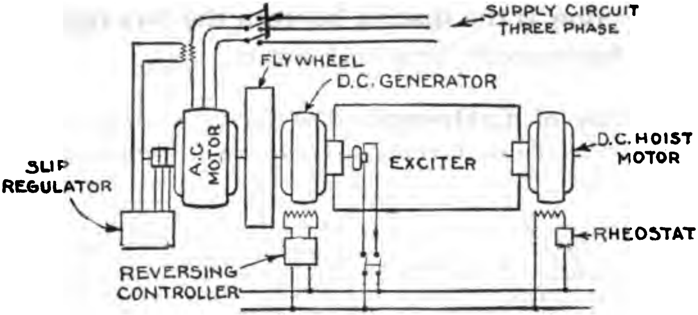


FIG. 5,897.—Direct current hoist motor with fly wheel equalizing motor generator set. When direct current motors are employed, a shunt wound direct current motor is used to drive the hoist the motor being supplied with power from a direct current generator, usually driven by a three phase induction motor supplied from the available power circuit. The essential feature of this system is that the voltage supplied to the hoist motor, and consequently the speed of the motor, is controlled by controlling the field current of the generator, instead of by varying the resistances in the armature circuit of the motor; thus, as the field current of the generator is increased from nothing to a maximum, the motor speeds up from standstill to full speed and if the field current of the generator be reversed, the motor reverses its direction of rotation. This system enables a very exact control of the speed to be obtained, because the speed of the motor is practically proportional to the strength of the generator field, whatever the load on the motor may be, while with any control system, where resistances are inserted in the armature circuit of the motor, the speed would vary within very wide limits with a change of load, rendering the exact speed control impossible. The control of the generator field involves scarcely any waste of electric power, but where resistances are inserted in the armature circuit, the loss of power becomes usually very great. The field currents of the generator are small, so that the control mechanism is small, compact, and very easy to handle.

Drums for mine hoists.—The most generally used type of hoist for service in mines is the drum type, the drum being either cylindrical or conical or a combination cylindrical-conical. To permit the adjustment of the length of the ropes for hoisting from different levels, it is customary to use two drums mounted on the same shaft, one being keyed to the shaft and the other being driven by it through some form of clutch. The cylindrical drum hoist is the type almost universally used for comparatively shallow shafts, and very frequently for the deeper ones. ***It consists of*** two cylindrical drums upon which the rope is wound in one or more layers, the diameter of the drums varying from 5 to 25 feet. In the conical drum hoist, the ropes are wound in single layers on two large cones, the rope being wound from the small to the large end of the cone. The use of this type of hoist is limited to comparatively shallow shafts, for depths below which the use of the conical drum is impracticable, it is necessary to compromise, using a drum combining the features of the cone and cylinder. The rope is wound from the small end of the cone over the conical part of the drum in a single layer, and then onto the cylindrical portion in one or more layers, depending upon the length of the rope.

Types of drive for mine hoists.—According to the method of drive, electric hoists may be divided in two classes: 1, those driven by induction motors, and 2, those driven by direct current motors. As the power supply in almost all cases is alternating current, the latter system requires provision for converting the current, this being always done by motor generators. The induction motor driven hoist is very simple, the motor being of the wound rotor type, and the speed controlled by inserting resistance in the rotor circuit. Drum and magnetic contactor control is used for the smaller sizes, while for the larger it is customary to employ a liquid rheostat. The contacts of this rheostat are usually stationary and the resistance is varied by changing the level of the liquid. High speed induction motors have very good electrical characteristics, and this method of drive is very suitable for large hoists operating with high rope speeds. The motor may be either direct connected or geared to the drum shaft, depending upon which method works out most economically.

Ques. How is the spacing between the cars regulated?

Ans. Automatically by a block system.

Essentials of Cableways.—The term cableway may be defined as a rectilinear *hoisting and conveying apparatus supported by a cable*.

The elements of construction are shown in fig. 4,242. A strong steel wire rope or cable is stretched between the towers BB′. On this rope runs the carriage C, pulled backwards and forwards by the hauling rope D, which is operated by the capstan drum E. One end of the hoisting rope F, is secured to the carriage, and is led round the various pulleys shown and to the hoisting drum G.

The slack of the hoisting rope, when paying out, is supported by the carriers H. These carriers are dropped by the carriage when running from B to B′, and are picked up again when returning from their position, being determined by buttons of different size arranged on the rope. Loads are hoisted and lowered by drum G, driver E, being held by its brakes.

To travel the load, the two drums are clutched together. Driver E, then hauls the carriage along, while drum G, takes in or pays out the hoisting rope, so that the vertical position of the load is unaltered.

Ques. What is the range of the apparatus?

Ans. It will take up and deposit loads anywhere along a line directly underneath the main cable, and by means of switch blocks it may be made to serve an area having a width of about 15 feet or so each side of the cable.

NOTE.—***Telpher performance.*** The loads hoisted and conveyed on telpher hoists have been as high as fifteen tons. The maximum speed of conveying on a straight level track is about 1,000 feet per min. The running speed is reduced at curves, according to their radii. For terminal work, the capacity of each hoist is two tons at 60 feet per min. (18.288 m. per min.) Two hoists can be combined so as to raise four tons. The motors being series wound, the speed of hoisting will increase as the load is diminished. For freight, handling from two to four carriage hoists constitute a train which has a total maximum carrying capacity of eight tons. Such trains are used for assorting as well as for distributing, according to consignments.

CHAPTER 90

ROPES, KNOTS AND SPLICES

Ropes.—Hemp, cotton, or wire is used in the manufacture of ropes. Hemp rope is very largely used because of its strength and durability.

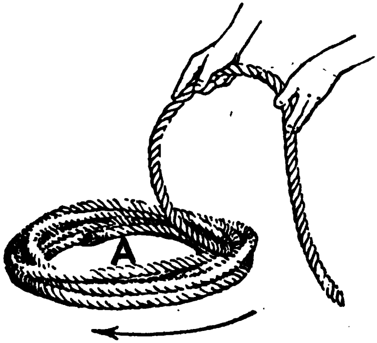


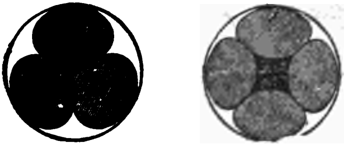
FIG. 5,898.—Method of coiling and uncoiling a rope. Because of the way in which rope is twisted in manufacture, it should always be coiled around "with the sun," or clockwise, as shown. *In uncoiling,* the end last laid down should never be pulled up from the top of the coil, because if this be done, the rope will twist and kink. These kinks will jam in the pulley blocks, and if pulled through they will seriously injure and weaken the rope. In uncoiling, therefore, the end first laid down should be pulled up through the center of the coil, as at A, or if for some special reason the end last laid down must be drawn out first, the whole coil should be turned over and this end drawn up through the center. *In general,* if a rope twist and kink in uncoiling, the coil should be turned over and the end being drawn passed up through the center of the coil. The same remarks apply to binder twine; if the wrong end be drawn out, the twine soon kinks, catches and breaks.

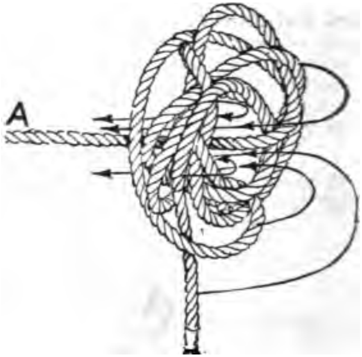
Of late years the supply of true hemp has been insufficient to fill the demand, and a substitute has been found in the outer fibers of the leaves of a species of the banana plant grown in the

Philippine Islands. The prepared fiber is exported from the city of Manila under the name of "Manila hemp," the rope made from it being called manila rope.

Cotton rope is used where its softness is desirable, as for instance in making halters for young animals having tender skins.

In manufacturing rope the fibers are first spun into a "yarn," this yarn being twisted in a direction called "right hand." A number of yarns are then put together and twisted in the opposite direction, or "left hand," into a "strand." Three of these strands for a three strand or four for a four strand rope are then twisted together, the twist being again in the "right hand" direction.





FIGS. 5,899 and 5,900.—End views of three and four strand ropes of the same size, a circle having been drawn about each in order that their solidness may be compared. In the three-strand rope the strands are larger than those in the four-strand rope and yet the circle in fig. 5,899 is not so well filled as in fig. 5,900. From this it is seen that four strand rope differs from three strand rope in that the former is stronger and more pliable, has a more even surface, weighs more per foot, and *being constructed on a core,* the strands are kept away from the center thus reducing chafing as the rope is bent around a pulley. The extra cost of the four strand rope is justified if the rope be properly cared for.

FIG. 5,901.—How to undo a snarl: ***Begin*** by loosening it, drawing out one end as far as possible as at A, and then opening the center of the snarl so as to form a hole of considerable size around the rope A. The whole bundle of tangled rope is then seized and forced through the hole thus made, putting the outside part of the bundle through first as shown by the arrows, a process much like kneading bread. This will add a little straight rope to the end A, and if patiently continued, the process will surely unravel the worst possible tangle.

When the strand is twisted it untwists each of the yarns, and when the three or four strands are twisted together into rope it untwists the strands but again twists up the yarns. It is this opposite twist that keeps the rope in its proper form. When a weight is hung on the end of a rope the tendency is for the rope to untwist and become longer.

In untwisting the rope it will twist the threads up and the weight will revolve until the strain of the untwisting strands just equals the strain of the yarns being twisted tighter.

In making a rope it is impossible to make these strains exactly balance each other. It is this fact that makes it necessary to take out the "turns" in a new rope, that is, untwist it when it is at work. The amount of twist that should be put in the yarns has been ascertained approximately by experience.

Figs. 5,899 and 5,900 show appearance of three and four strand rope.

In the following table the figures refer to average grade Manila rope, new and *without knots*.

Properties of Three Strand Manila Rope*

I	II	III	IV		V	VI	VII
Diameter (Inches)	Circumference (Inches)	Weight of 100 feet of rope (Pounds)	Length of each pound of rope Ft.	Ins.	Safe load (Pounds)	Breaking load (Pounds)*	Diameter of pulley (Inches)
3/16	9/16	2	50	0	35	230	1 1/2
1/4	3/4	3	33	4	55	400	2
5/16	1	4	25	0	90	630	2 1/2
3/8	1 1/8	5	20	0	130	900	3
7/16	1 1/4	6	16	8	175	1,240	3 1/2
1/2	1 1/2	7 2/3	13	0	230	1,620	4
5/8	2	13 1/3	7	6	410	2,880	5
3/4	2 1/4	16 1/3	6	1	520	3,640	6
7/8	2 3/4	23 2/3	4	3	775	5,440	7
1	3	28 1/3	3	6	925	6,480	8
1 1/8	3 1/2	38	2	7	1,260	8,820	9
1 1/4	3 3/4	45	2	2	1,445	10,120	10
1 3/8	4 1/4	58	1	8	1,855	13,000	11
1 1/2	4 1/2	65	1	6	2,085	14,600	12
1 3/4	5 1/4	97	1	0	3,070	21,500	14
2	6	113	0	10	3,600	25,200	16
2 1/2	7 1/2	184	0	6½	5,630	39,400	20
3	9	262	0	4½	8,100	56,700	24

* From the rules by C. W. Hunt and Spencer Miller.

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*NOTE.—It should be noted that ***knots weaken a rope***. The safe load given in the table is the greatest load that a single rope should carry, being about 1/7 of the breaking load. The data is from C. W. Hunt & Co.

Ropes and cordage are so peculiarly a sailor's province that nautical expressions must necessarily be used. Accordingly a few explanations will first be given of terms used in this connection:

Belay.—To make fast the end of a tackle fall, etc., at the conclusion of a hoisting operation or the like.

Bend.—A fastening of one rope to another or to a ring, thimble, etc.

Bight.—The loose part of a rope between two fixed ends.

Haul.—To heave or pull on a rope.

Hitch.—A fastening of a rope simply by winding it, without knotting, around some object.

Knot.—A fastening of one part of a rope to another part of the same, by interlacing them and drawing the loops tight.

Lay.—To twist strands up together as in rope making, the fibre or tow receiving a right handed twist to make yarns, yarns being laid left handed into strands, and strands right handed into ropes. Three strands make a hawser, and three hawsers are laid up into a cable.

Make fast.—To secure the loose end of a rope to some fixed object.

Marline spike.—A long tapered steel instrument used to unlay or separate the strands of rope for splicing, etc., or for working marline around a seizing.

Parcelled.—Wrapped with canvas, rags, leather, etc., to resist chafing.

Seize.—To lash a rope permanently with a smaller cord.

Serve.—To lash with cord, etc., wound tightly and continuously around the object.

Splice.—To connect ropes' ends together by unlaying the strands of each and then plaiting both up together so as to make one continuous whole.

Strand.—Two or more larger yarns twisted together.

Taut.—Stretched or drawn tight, strained.

Yarn.—Fibres twisted together.

The rope fastenings most necessary for the purpose of the outside engineer or millwright here described, have an illustration of each one which has been tested by an expert and found abundantly clear to show the mode of procedure.

Knots used for making loops on the ends of ropes come first in order, and these comprise:

Bowline.—A most useful knot, making a loop that will not slip or tighten; to be recommended for all purposes that it will fulfil; fig. 5,902.

Bowling on a bight.—Used to make a loop in the bight of a rope, or with a doubled rope; fig. 5,903.

Slip Knot.—Ordinary running noose, tightening as strain is applied; fig. 5,904

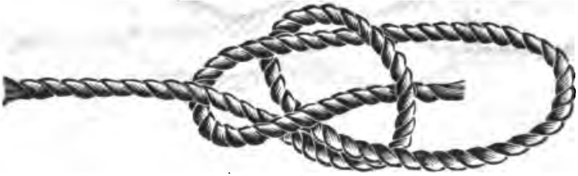


FIG. 5,902.—Bowline.

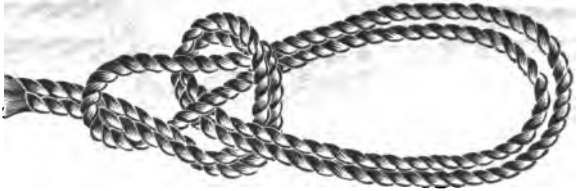


FIG. 5,903.—Bowline on a bight.

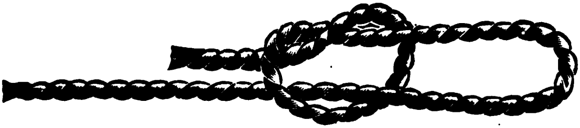


FIG. 5,904.—Slip knot.

Next in order come the *knots and bends used for tying two ropes together*. These are:

Carrick Bend.—For connecting the ends of two equal ropes; fig. 5,905.

Reef or Square Knot.—Used to fasten the reef points of a sail; a neat, non-slipping knot that lies quite flat, and is easily untied; fig. 5,906.

Sheet Bend or Weaver's Knot.—For tying together two ropes of different sizes; fig. 5,907.

Various methods of *securing the ends of ropes* next demand consideration, and these vary greatly with the diversity of the object sought to be attained.

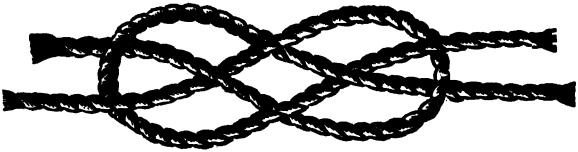


FIG. 5,905—Carrick bend.

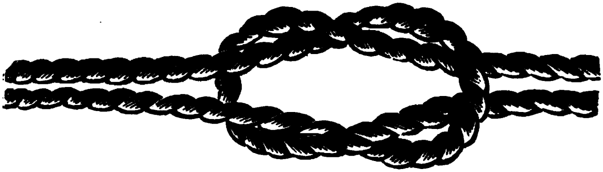


FIG. 5,906.—Reef or square knot.

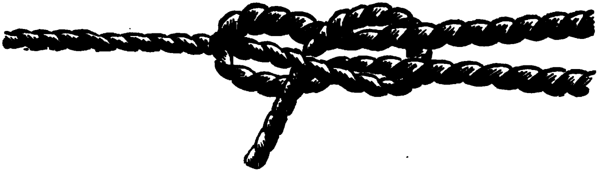


FIG. 5,907.—Sheet bend or weaver's knot.

Blackwall Hitch.—For making fast a rope over a belaying pin or crane hook, not very trustworthy; fig. 5,908.

Clove Hitch.—To make fast a line to a spar; will stand a vertical pull without slipping; fig. 5,909.

Double Hitch.—For similar purposes, but safer than the Blackwall hitch. Care must be exercised, with this hitch and the preceding one, that the strain comes upon the part of the rope marked S for strain; fig. 5,910.

Fisherman's Bend.—A convenient and neat manner of making fast a rope's end, especially to a ring bolt or cleat; fig. 5,911.

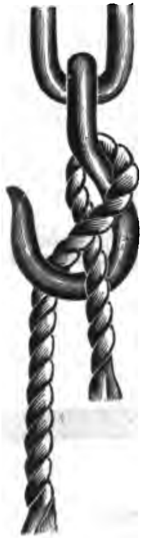


FIG. 5,908.—Blackwall hitch.

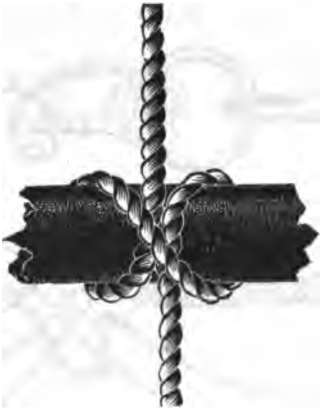


FIG. 5,909.—Clove hitch.

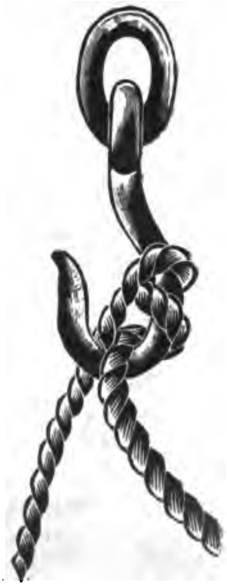


FIG. 5,910.—Double hitch.

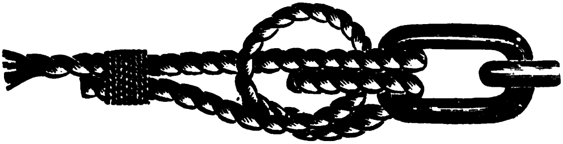


FIG. 5,911.—Fisherman's bend.

Round turn and Half Hitch.—For seizing a rope to an eyebolt or ring; fig. 5,913.

Round turn and two Half Hitches.—A simple means of making fast the end of a rope or blockfall. Supposed by sailors to be characteristic of an engineer; fig. 5,912.

The methods of *splicing* two ropes together, by incorporating their strands together, differ according to the services required. Chief among them are:

Short Splice.—Quickly made; useful for strops or slings; makes a lump on the rope, and therefore is not recommended for driving or hoisting ropes; fig. 5,914.

Long Splice.—Necessary for ***main driving ropes*** or for ***block falls*** which have to be rove through a pulley, and in which no increase of thickness is desirable.

After splices, consideration must be given to methods of *fixing ropes around thimbles or bars*. Three good styles are:

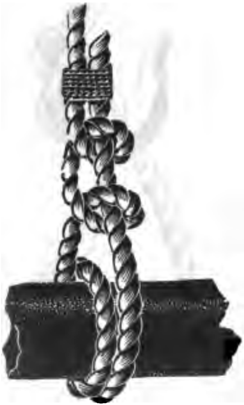


Fig. 5,912.—Round turn and two half hitches.

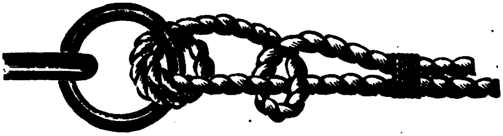


Fig. 5,913.—Round turn and half hitch.

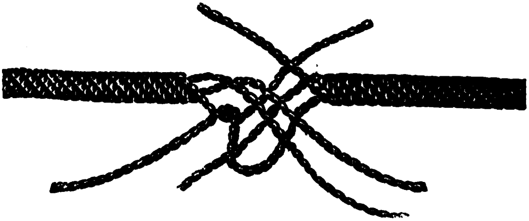


Fig. 5,914.—Short splice.

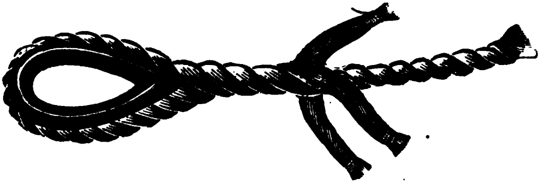


Fig. 5,915.—Eye splice.

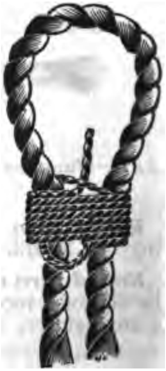


Fig. 5,916.—Round seizing.

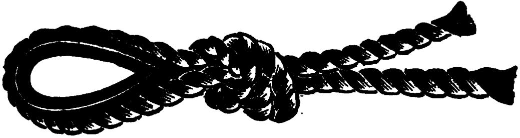


Fig. 5 917.—Flemish loop.

Eye Splice.—The permanent method of bending a rope around a thimble or grummet: the loose end is spliced into the centre of the rope; fig. 5,915.

Flemish Loop.—A neat and safe method of temporarily fixing a thimble in a rope, with a slip-noose and round turn; fig. 5,917.

Round Seizing.—An attractive style for making a permanent loop in a rope; fig. 5,916.

Occasionally it is desirable to *shorten a rope* considerably without having recourse to cutting it; for such purpose the *sheepshanks*, shown in fig. 5,918, is invaluable.

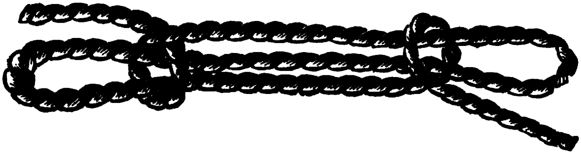


FIG. 5,918.—Sheep shanks.

The last series of fastenings are those used for *connecting block-ropes, etc., to the objects which have to be lifted*. Among these are:

Lashing with Knot.—A convenient method of improvising a sling; fig. 5,919.

Stevedore's Knot.—For making fast a block rope to the handles or cord of a package; fig. 5,920.

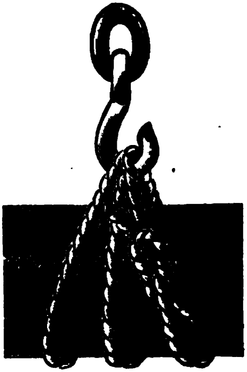


FIG. 5,919.—Lashing.

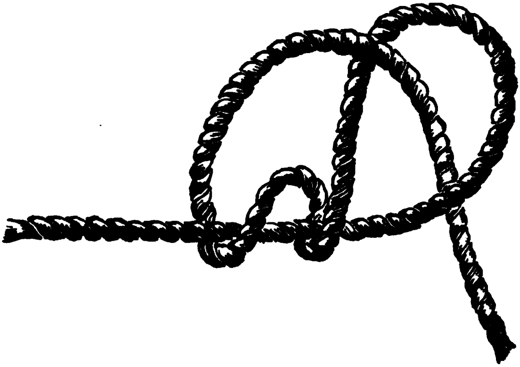


FIG. 5,920.—Stevedore's knot.

Strop or Sling.—An endless rope made by splicing; the illustration shows its application to an object whose end is inaccessible, or which has no eyes to hook into; fig. 5,921.

Timber Hitch.—For hoisting, etc., cannot slip; the harder the pull, the tighter it grips; fig. 5,922.

Timber Hitch and Round Turn.—Useful for towing a spar, or for lifting one endways; specially adapted for standing a lengthwise strain; this is sometimes termed the *floating spar hitch*; fig. 5,923.

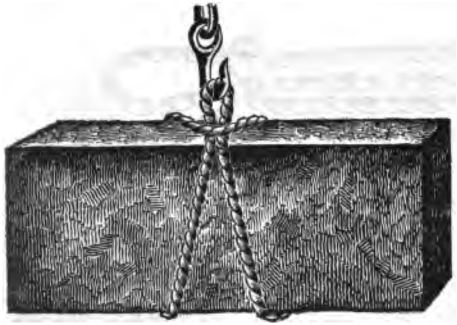


FIG. 5,921.—Strop or sling.

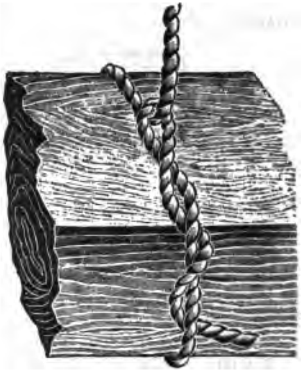


FIG. 5,922.—Timber hitch.

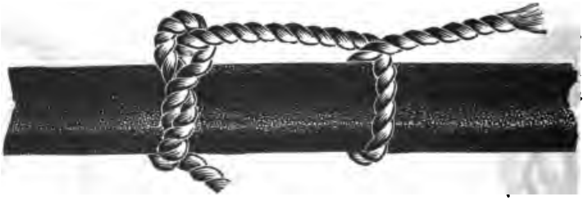
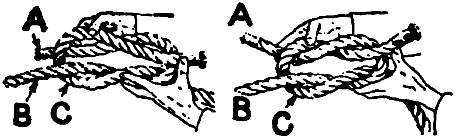
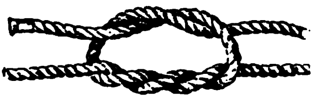


FIG. 5,923.—Timber hitch and round turn sometimes called floating spar hitch.

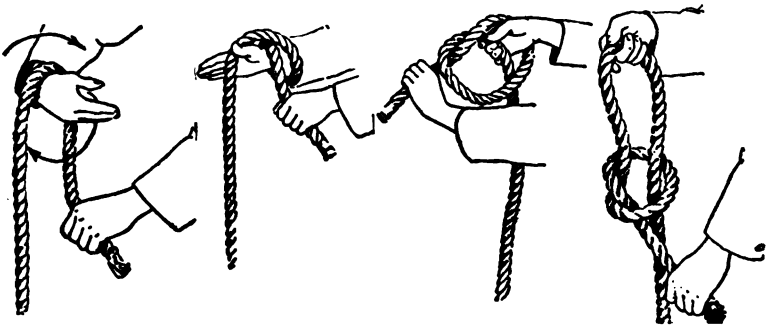
Theory of Knots.—According to Kent, the principle of a knot is that "no two parts which would move in the same direction if the rope were to slip, should lay along side of and touching each other." Another principle that should be added to the above is that a knot or a hitch must be so devised that the *tight part of the rope must bear on the free end in such a manner as to pinch and hold it, in a knot, against another tight part of the rope, or in a hitch, against the object to which the rope is attached.*



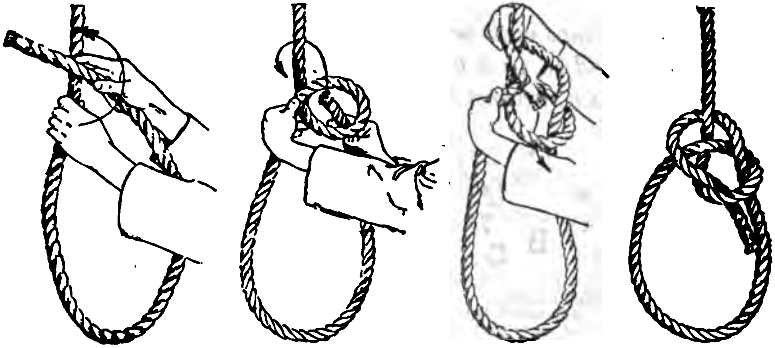


FIGS. 2,924 and 2,925.—Granny knot. This is frequently made by mistake for a square knot. It tends to slip under strain and is very hard to untie when set. The point at which a granny knot may be detected is in the position shown in fig. 2,924. Ropes A and B are not on the same side of C, as they should be in making a square knot, and when the knot is completed they are still wrong, as shown in fig. 2,925.

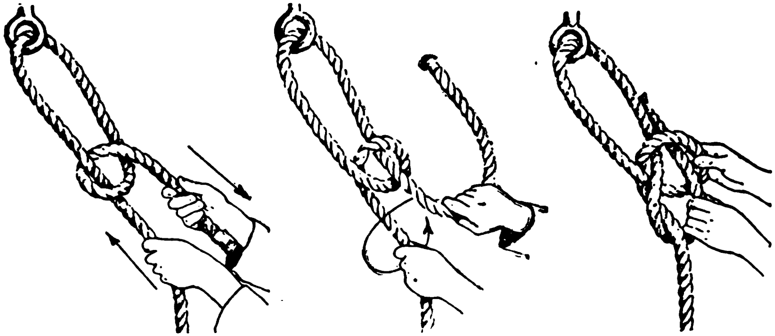
FIG. 2,926.—Surgeons knot. The left end of one rope is first wrapped twice around the other rope, instead of once as for the square knot. If now the rope be pulled up tightly, the extra twists tend to keep the knot from slipping while the second part of the tie is made. ***In using*** this knot with smooth cord, as in tying bundles, after the first wraps have been taken and the cord drawn up firmly, it is necessary to kink the double twists into a bunch so as to jam them, by swinging the hands around in such a manner that the wrists cross, while still pulling. The knot will then hold securely while the second part of the tie is made and drawn up tightly.



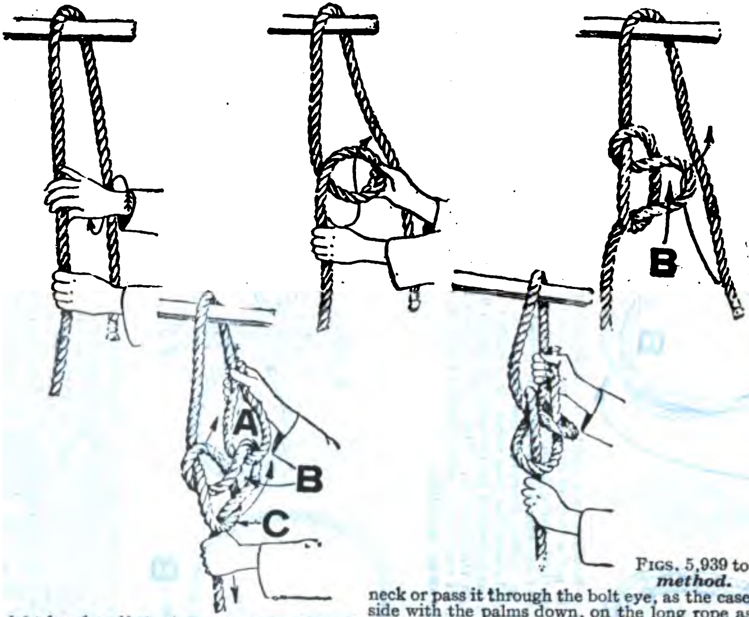
FIGS. 2,927 to 2,930.—Slip knot. It may be made by starting either with the position shown in fig. 2,927 or with that in fig. 2,929, whichever be easier for the person tying the loop. When beginning with fig. 2,927, grasp the end of the rope in the left hand and, bringing the right hand upward, pick up a bight of the rope on the wrist as shown. Bend the right wrist so that the palm of the hand is upward and the little finger touches the short end of the rope. Then rotate the wrist as shown by the upper arrow. This will cross the sides of the bight and form a loop around the wrist, and at the same time will bring the main rope in between the thumb and the first finger as shown in fig. 2,928 and as indicated by the lower arrow in fig. 2,927. Grasp the main rope and draw a bight up through the loop, as shown in figs. 2,929 and 2,930. In starting with the position shown in fig. 2,929, the end is held in the left hand and the loop formed by twirling the rope to the right between the thumb and the fingers of the right hand. Either method is easy, provided the end is held in the left hand at the beginning.



FIGS. 5,931 to 5,934.—Bowline knot. *I. Overhand method.* With the right hand lay the end of the rope over the long rope, and with the left hand grasp the long rope below the crossing, as in fig. 5,931. Hold the right hand stationary, and with the left hand bring the long rope up and over to form a loop about the end, as indicated by the arrow in fig. 5,931 and as shown in fig. 5,932. With the right hand draw the end up through the loop and pass it around behind the long rope from right to left, as indicated by the arrow in fig. 5,932 and as shown in fig. 5,933. Pass the end forward and down into the loop again from above, as indicated by the arrow in fig. 5,933 and as shown in fig. 5,934. Note that this knot consists of a loop with a bight up through it, the bight going around behind the long rope. The bowline knot is the best knot known for forming a loop that will not slip under strain and that may be easily untied. The overhand method is used when standing opposite the end of a slack rope and making a loop that is not fastened to any object.



FIGS. 5,935 to 5,937.—Bowline knot. *II. Underhand method.* Pass the rope through the eye or around the object from left to right, holding the long rope in the left hand. Take a half hitch around the long rope, starting it by passing the end across over the long rope (see fig. 5,935). Now transfer the loop from the short rope to the long rope. This is done by giving slack with the left hand and pulling up with the right, as indicated by arrows in fig. 5,935. With the loop transferred to the long rope and the end passing through it, as in fig. 5,936, it is necessary only to bring the end from left to right under the long rope, as indicated by the arrow in fig. 5,936, and back into the loop from below, as shown in fig. 5,937. The knot is now ready to be tightened up, when it will be finished. The underhand method is used when standing alongside the rope and making a loop around some object or through an eye.



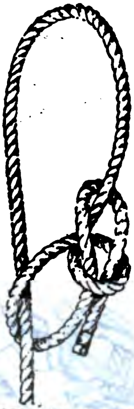
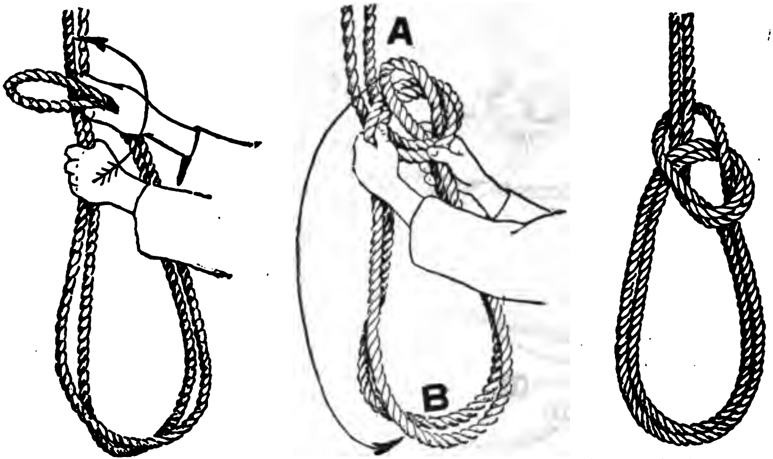
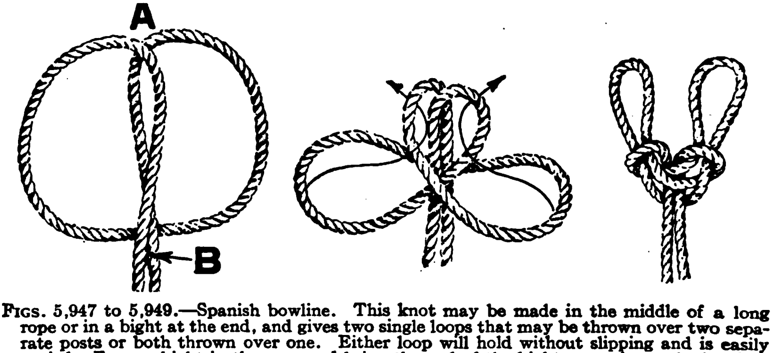


FIG. 5,938.—Running bowline. This is simply a slip knot wherein the loop through which the rope slips is formed by using the bowline knot, as already described.

FIGS. 5,939 to 5,943.—Bowline knot. ***III. Texas method.*** Throw the rope over the horse's neck or pass it through the bolt eye, as the case may be. Lay both hands, side by side with the palms down, on the long rope as shown in fig. 5,939. Rotate the right hand as if the forearm were a long pivot, as indicated by the arrow in fig. 5,939, and thus form a loop as in fig. 5,940. With the left hand push a bight of the long rope from left to right through this loop, as indicated by the arrow in fig. 5,940 and as shown at B, fig. 5,941. Reach under the horse's neck, grasp the short end of the rope, and pass it upward through bight B, as indicated by the arrow in fig. 5,941. Draw the end up until the loop about the horse's neck is of the size desired, bend the rope end back on itself to form bight A (fig. 5,942), and grasp both sides of the bight with the right hand as shown. Downward pulling on the long rope will straighten bight B, and will force loop C, up over bight A, as indicated by the arrows in fig. 5,942 and as shown in fig. 5,943. Continue pulling until the knot is set firmly. The Texas method, like the underhand method, is used in making a bowline knot when standing alongside the rope; it is particularly useful in fastening a tie rope about a horse's neck, since the size of the loop is easily adjusted.



Figs. 5,944 to 5,946.—Bowline on a bight. To make a loop with a bowline knot in the middle of a long rope, or to get a loop of double rope at the end of a rope, a bowling knot is tied by the overhand method, using a bight of the rope instead of a single rope. The steps indicated in fig. 5,944 are the same as those described for fig. 5,931. After arriving at the position shown in fig. 5,945, however, the knot is made differently. Instead of bight A, being passed around behind the long ropes, it is pulled up through the small loop and then brought downward, as indicated by the arrow in fig. 5,945, and the whole of the large loop B, is passed through the bight A. The bight is then brought back to its starting point and loop B, is pulled out again, which brings bight A, down into place and produces the finished knot as shown in fig. 5,946.

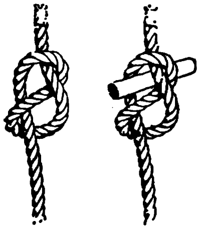


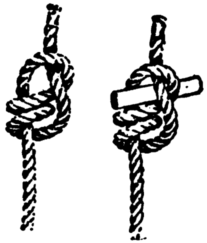
Figs. 5,947 to 5,949.—Spanish bowline. This knot may be made in the middle of a long rope or in a bight at the end, and gives two single loops that may be thrown over two separate posts or both thrown over one. Either loop will hold without slipping and is easily untied. Form a bight in the rope and bring the end of the bight up underneath the sides at point B, fig. 5,947, thus forming two loops. Cross the sides of the bight at A, in the same figure. Grasp this crossing and fold it down on point B, thus forming two new smaller loops as shown in fig. 5,948. Pass the end of each large loop back through the nearest small loop, as indicated by the arrows in fig. 5,948, pull these loops out hard, and the knot is finished (fig. 5,949).

The principle is illustrated in the Stevedore's Knot, figs. 5,952 and 5,953 and in the half hitch fig. 5,954.

The elements of a knot or bends that a rope undergoes in the formation of a knot or of a hitch are of three kinds:

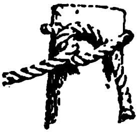
1. Bight.
2. Loop or turn.
3. Round turn.

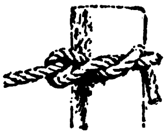




FIGS. 5,950 and 5,951.—Figure eight knot. This is used for making a knob on the end of a rope or for keeping the strands from untwisting. It may be easily untied. Form a bight near the end of the rope, give the short end one complete turn about the long rope, and pass it up into the bight (fig. 5,950). Pull up tightly, so that the end is square across the rope. By putting in a short stick, or shackle, as shown in fig. 5,951, the knot may be very easily untied.

FIGS. 5,952 and 5,953.—Stevedore's knot. This knot is used for making an extra large knob on the end of a rope. It is tied the same as a figure-eight knot, except that two turns are taken around the rope instead of one, and it may be made either without or with a shackle as in fig. 5,952 and in fig. 5,953.





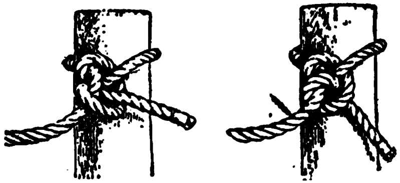
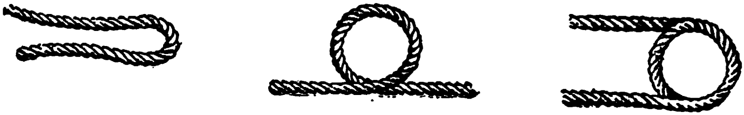


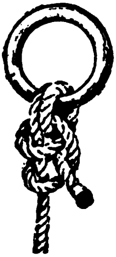
FIG. 5,954.—Half-hitch. This is a temporary and not very secure fastening. In the figure the half-hitch is shown taken around the main rope and, as shown, it consists merely of a loop around the rope with the free end pinched between the rope and the object to which it is attached.

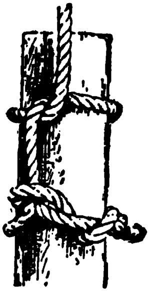
FIG. 5,955.—Timber-hitch. This is a secure temporary fastening very easily undone, which is used to a considerable extent by carpenters for raising timbers. ***To make,*** pass the rope around the timber, take a half-hitch around the rope, and then pass the free end once more between the rope and the timber, as shown.

FIGS. 5,956 and 5,957.—Two half-hitches. Fig. 5,956, ***wrong*** way; fig. 5,957 ***right*** way. This is a good fastening and is secure provided it is well pulled down and set before being subjected to a load. If tied according to fig. 5,957, the hitches are easily loosened, but if made as shown in fig. 5,956, they will jam tightly.



Figs. 5,958 to 5,960.—Elements of a knot. Fig. 5,958 bight; fig. 5,959, loop or turn; fig. 5,960, round turn. In fig. 5,958 the bight is formed by simply bending the rope, keeping the sides parallel; in fig. 5,959, the loop or turn is made by crossing the sides of a bight; in fig. 5,960 the round turn is produced by further bending one side of a loop.





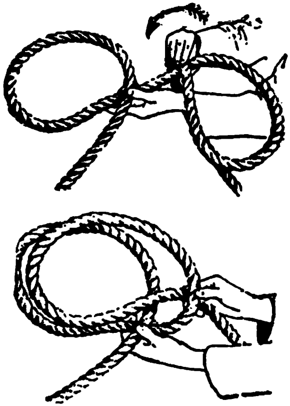
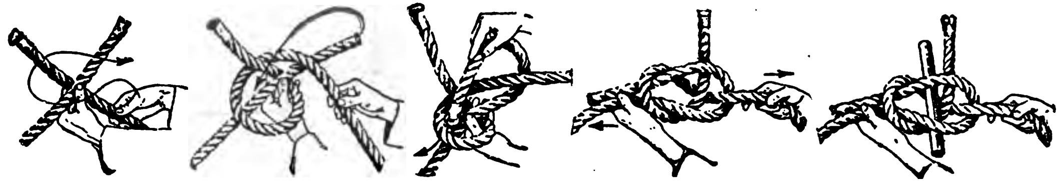


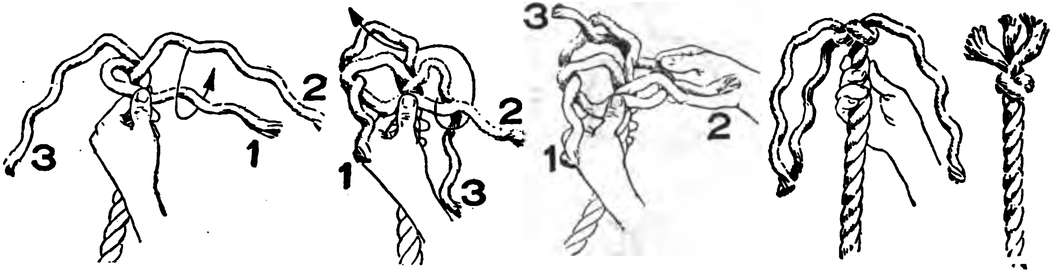
Fig. 5,961.—Anchor bend. This hitch, also called fisherman's bend, is used for fastening a rope securely to a metal ring, such as that on an anchor, with a double rope in contact with the metal to prevent excessive wear. ***To make,*** take a round turn around the ring and then two half hitches around the rope, passing the end for the first half hitch through the loop of the round turn as shown. In this form the hitch is very secure, but it may be made more so by whipping the end to the main rope.

Fig. 5,962.—Combined timber, and half hitch. This secure fastening is useful in handling long articles that must be kept in line with the pull of the rope. Note that the half hitch is around the object this time, and not around the rope.

Figs. 5,963 and 5,964.—Clove hitch. ***This consists of*** two half hitches arranged for fastening a rope around an object. It may be made in the middle of a long rope without access to the ends, and will stand a pull from either direction without slipping when once properly set. It is easily undone and is a very useful hitch. 1. ***Beginner's method:*** By twisting the rope to the right with the right hand, form two loops in a figure eight with the ends of the rope side by side at the center and extending in opposite directions, as shown in fig. 5,963. By still further twisting the right hand in the same direction, as indicated by the arrow in fig. 5,963, the hitch is thrown into the completed form as shown in fig. 5,964. Put the loops over the object and pull taut. 2. ***Hand and toe method:*** This is used by sailors for heavy rope. Draw the rope along the floor from left to right across the toe of the right foot, and then swing it around back again from right to left, forming a loop. With the foot turn the whole loop upside down and over to the left. Then form a second loop by swinging the rope around in the same direction as before. The loops will then be arranged as in fig. 5,963, except that the left hand rope will in this case come down from above instead of up from below as in the picture, and the right hand one will go from below upward. Pick up the loops, folding them together as in fig. 5,964.



FIGS. 5,965 to 5,969.—Weavers **knot.** **Cross the ends, the right** under the **left, as in fig.** 5,965. **With the right hand** pass the right rope from left to right to form a loop around its own end passing twice above the left rope, as indicated by the arrow in fig. 5,965, and as shown in fig. 5,966. Release the right rope, and with the right hand bend back the end of the left rope into the loop just formed, as indicated by the arrow in fig. 5,966 and as shown in fig. 5,967. Pull the end well through, grasp the ropes as shown in fig. 5,968, and draw the knot tightly as indicated by the arrows. If it be desired to untie the knot quickly, insert a wooden stick as a shackle as shown in fig. 5,969. The Weaver's knot is a secure fastening, capable to being made with great rapidity and easily untied. It is universally used by weavers for tying threads and yarns.

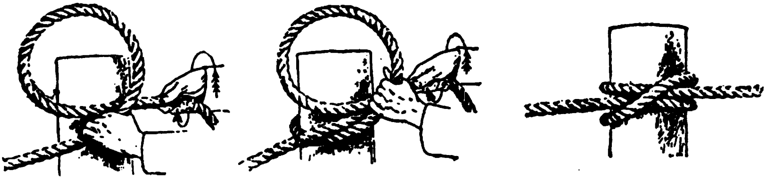


FIGS. 5,970 to 5,974.—Wall knot. When a small knob on the end of a rope is desirable, or when such a knot is not objectionable and a quick and secure method of fastening the strands is needed, the wall knot may be used. ***To make a wall knot:*** unlay the rope for five or ten inches or more, depending on the size. Holding the rope in the left hand with the loose strands up, take any strand, as No. 1, lay it down and across the rope with the end toward the right, and hold it in place with the left thumb as in fig. 5,970. Take the next strand to the right No. 2, and pass it around the end of No. 1 as shown by the arrow in fig. 5,970. Before releasing No. 2 take the left thumb off No. 1 and use it to hold No. 2 and up through the loop of No. 1 as indicated by the arrow in fig. 5,971 and as shown in fig. 5,973. The knot should next be tightened by pulling all of the strands, one after the other until appears as in fig. 5,973. The last steps are to pull the strands closely together in the center, roll the knot toward the end of the rope to hold them, and cut the strands sufficiently long to insure their not pulling back.

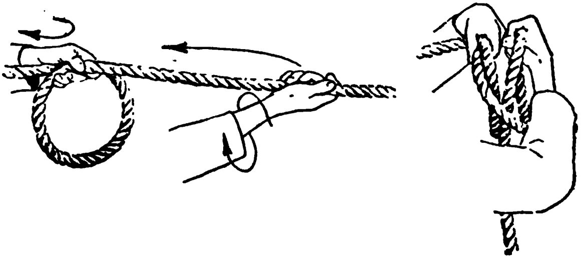
These are shown in figs. 5,958 and 5,960.

Knots and hitches are made by combining these elements in different ways conforming to the principles of a knot given above.

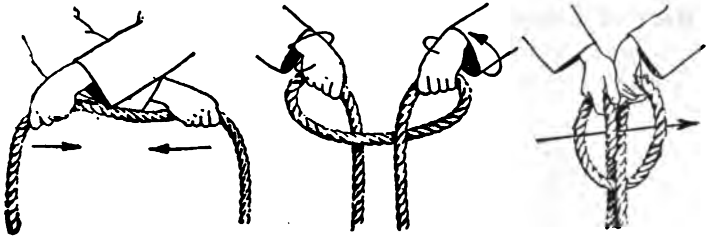
For example, the half hitch (fig. 5,954) is a loop around a rope, with the free end locked under the rope; the clove hitch (fig. 5,977) consists of two loops over a post; the sheepshank (fig. 6,029) is a round turn and two loops; the bowline knot (fig. 5,934) is a loop with a bight through it and around the main rope; and the weaver's knot (fig. 5,968) is the same as the bowline knot, except that the ends take a somewhat different direction.



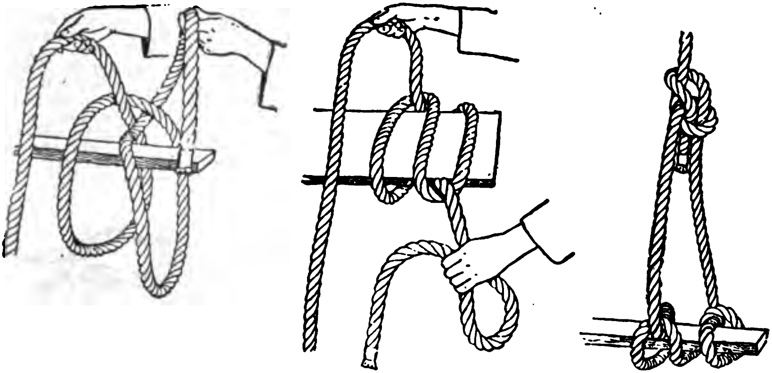
FIGS. 5,975 to 5,977.—Clove hitch. ***III. Sailor's method.*** In this method the hitch is made while there is a pull on the rope, as in mooring a boat. Sustain the strain on the rope with the left hand, as shown in fig. 5,975, and by twisting the rope to the right with the right hand, as indicated by the arrow, form a loop in the rope and then roll the loop over the top of the post. Move the left hand up beyond the loop, hold the rope there, and with the right hand form a second loop and roll it in place as shown in fig. 5,976. Note that in the finished hitch, fig. 5,977, the diagonal rope binds both ends against the post.



FIGS. 5,978 and 5,979.—Clove hitch. ***IV. Cowboy's method:*** Pick up the rope with the left hand, and with the right form a loop to be held by the left as shown in fig. 5,978. Grasp the rope farther out with the right hand. Without releasing the rope bring the hands upward and together as indicated by the arrows so that the knuckles of the left hand press the backs of the fingers of the right, as shown in fig. 5,979. Grasp all the ropes with either hand, and the hitch is ready for use. The advantages of this way of making the hitch are that in the first stage (fig. 5,978) the rope is very conveniently carried in the field while walking, and that the last state (fig. 5,979) is quickly made from the first.

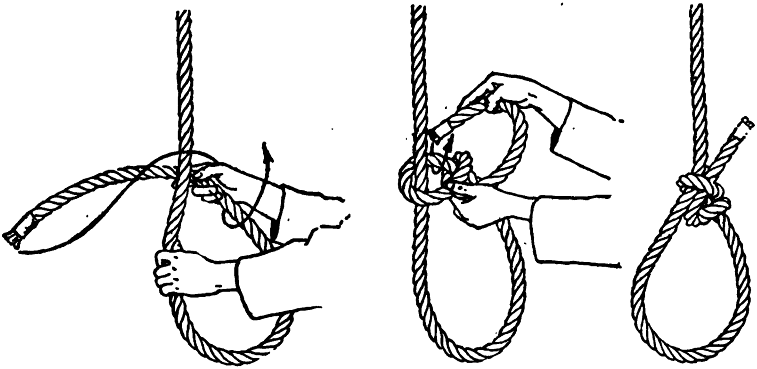


FIGS. 5,980 to 5,982.—Clove hitch. ***V. Circus method:*** Cross the arms in front of the body, the left outside the right, and pick up the rope as shown in fig. 5,980. Without twisting the wrists uncross the arms, as indicated by the arrows in fig. 5,980 and take the position shown in fig. 5,981. Now rotate both hands to the right as indicated by the arrows around the wrists, and put the knuckles of the left hand into the palm of the right, as shown in fig. 5,982. Slip the loop from the left hand into the right, and the hitch is ready. For most persons these drawings will be more easily followed if they are inverted. The circus method is the quickest way of making the clove hitch, and should be learned by everyone. It is especially useful in pitching large tents, when many ropes must be picked up from the ground and fastened to short stakes.

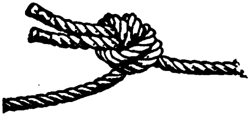


FIGS. 5,983 to 5,985.—Scaffold hitch. By the cowboy's or circus method form a clove hitch of ample size so that when placed over the end of the scaffold plank it will hang loosely below it, as in fig. 5,983. Draw to the left the rope in the left hand in fig. 5,983, and to the right the rope in the right hand in the same figure, thus gaining the position shown in fig. 5,984. Turn the plank over, draw the ropes up above it, join the short end to the long rope by an overhand bowline (fig. 5,984), pull the bowline tight, at the same time adjusting the length of the two ropes so that they hold the plank level, and the hitch is finished as shown in fig. 5,985. Attach a second rope to the other end of the plank in the same way and the scaffold is ready. Many occasions arise involving the need of a single board scaffold, hung by a single rope at each end. If a scaffold of this kind is to be safe, the ropes must be attached to the board in such a way that the board will not turn. The scaffold hitch fills the need.

Effect of Knots.—A rope is weakened by knots because in order to form a knot, the rope must be bent which brings most of the strain on the outside fibers; the overloading breaks the



FIGS. 5,986 to 5,988.—Jam hitch. Pass the cord around the package, bringing the short end beyond the long cord and from right to left, as shown in fig. 5,986. Bend the short end to the right to form a bight around the long cord, and then take a turn around the other side of the bight, as indicated by the arrow in fig. 5,986 and as shown in fig. 5,987. Pass the end upward inside the bight and next to the long cord, as indicated by the arrow in fig. 5,987 and as shown in fig. 5,988. Pull the hitch up tightly so as to pinch the long cord. It can now be slipped down to tighten the loop about the package, and if the cord be of the right kind and size it will jam and hold. The jam hitch is useful in tying up light packages, such as bundles of lath, small boxes, rolls of paper, and the like, a hitch that will slide along a cord in one direction, but will jam and hold against moving the other way, will be found exceedingly convenient. The jam hitch will answer these requirements, provided the cord used is large enough and of not too hard a body nor too smooth a surface.



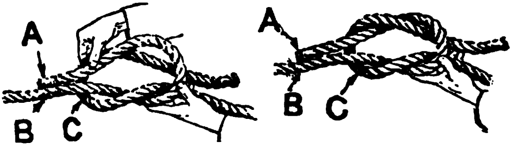


FIG. 5,989.—Grain binder knot. ***To make*** lay the ends side by side and tie an overhand knot in them as in fig. 5,989. The grain binder knot is the simplest way of joining two ropes, and the one used on the automatic binding attachments of all grain harvesting machines. ***A disadvantage*** is that the knot is difficult to untie when once pulled tightly.

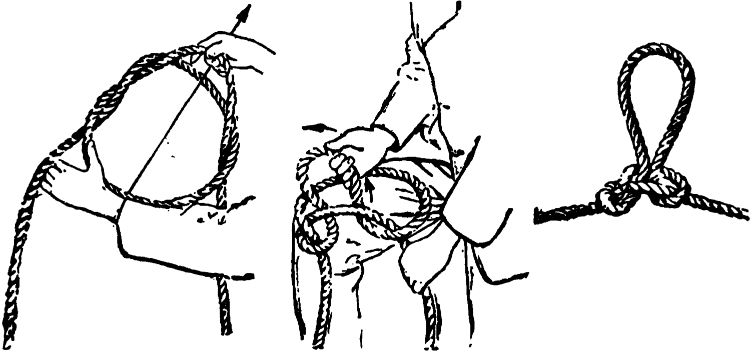
FIGS. 5,990 and 5,991.—Square knot. Cross the ropes, placing the right under the left, wrap the end of the left rope around the right, and bend each rope back on itself as in fig. 5,990. Note that ropes A and B are on the same side of C. Wrap A around the other rope end, producing the knot as in fig. 5,991, A and B being still on the same side of C. The square knot is most frequently used of all knots, it is secure when set and may be untied without difficulty. ***Caution:*** In making a square knot care should be taken not to make a granny knot by mistake.

outside fibers, increasing the strain on the fibers below which later break and soon the entire rope breaks.

From experiment by Prof. E. F. Miller the approximate efficiency of knots, hitches and splices is as given in the following table.

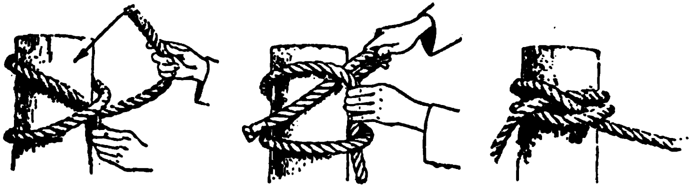
Efficiency of Knots, Hitches and Splices

	Straight rope	Eye-splice over an iron eye	Short splice	Timber hitch, anchor bend	Clove hitch, running bowline	Square knot, weaver's knot	Over-hand knot
Efficiency of the knot...........	100	90	80	65	60	50	45



FIGS. 5,992 to 5,994.—Harness hitch. Start a slip knot by making a loop and drawing a bight up through it, as in fig. 5,992, but pull the bight through only so far as shown in fig. 5,992. Now take the lower part of the loop, shown touching the left wrist in fig. 5,992, and pass it between the bight and the side of the loop as indicated by the arrow in fig. 5,992 and shown in fig. 5,994. To pull the knot up tightly and have it keep its form, lay it on the right knee or some other surface and draw the new bight through by pulley up its side toward the body, as indicated by the arrows in fig. 5,993. Pull the knot up tightly, attaining the finished form (fig. 5,994). *The harness hitch* is used by sailors for making loops in a towline. It does not weaken the rope very much and is easily untied.

Size of Pulleys.—A rope, as it goes around a pulley, is continually bending and straightening. The bending brings excess strain on the outer fibres and causes the strands to chafe each other at the center of the rope. Evidently the smaller the pulley, the worse the chafing.



FIGS. 5,995 to 5,997.—Miller's knot. Take a round turn about the neck of the sack or the fixed object crossing the ropes in doing so, as in fig. 5,995. Raise the main rope just above the crossing, pass the free end under, as in fig. 5,996, and draw up tightly (fig. 5,997). This hitch may be loosened by grasping either end of the rope and pulling it around to the right or left, as the case may be. *In tying sacks* it is convenient to hold the mouth of the sack shut with the left hand, and to wrap the twine around the sack and the little finger of the left hand in such a way that the finger is in the place of the upper rope's end in fig. 5,996. The twine is brought on around the sack, caught by the finger, and drawn back under the first wrap of twine in a direction diagonally upward from left to right. The miller's knot is especially adapted to tying up grain and flour sacks; it is also useful in place of a clove hitch in fastening a rope to an object whose ends cannot be reached, such as a post in a barn.

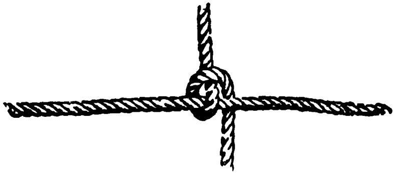
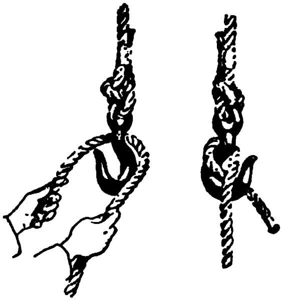
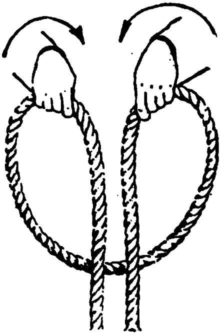


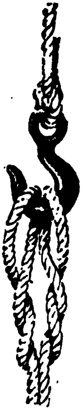
FIG. 5,998.—Crossing hitch. The purpose of this hitch is to prevent slipping at the crossing point of ropes or of twine. It is especially useful in tying up packages, and is so simple as to require no explanation.



FIGS. 5,999 and 6,000.—Blackwell hitch. Form a bight in the rope and pass it under and back of the hook, as shown. Cross the sides of the bight to form a loop about the shank of the hook, passing the free end between the hook and the main rope as in fig. 6,000. The Black well hitch is useful when it is necessary to attach a rope to a hook. A quick and secure temporary fastening is the blackwell hitch, which is simply a half hitch about the shank of the hook.

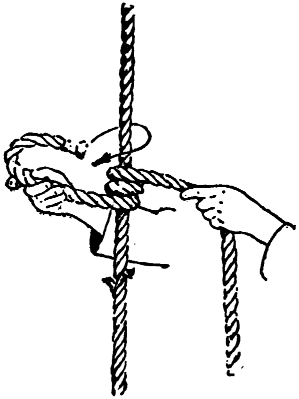
Since the chafing of a four strand rope is less than that of a three strand rope, one with four strands should be used especially if small pulleys be necessary.

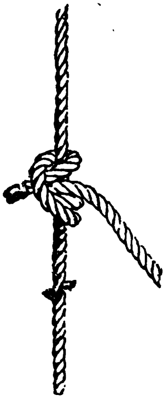


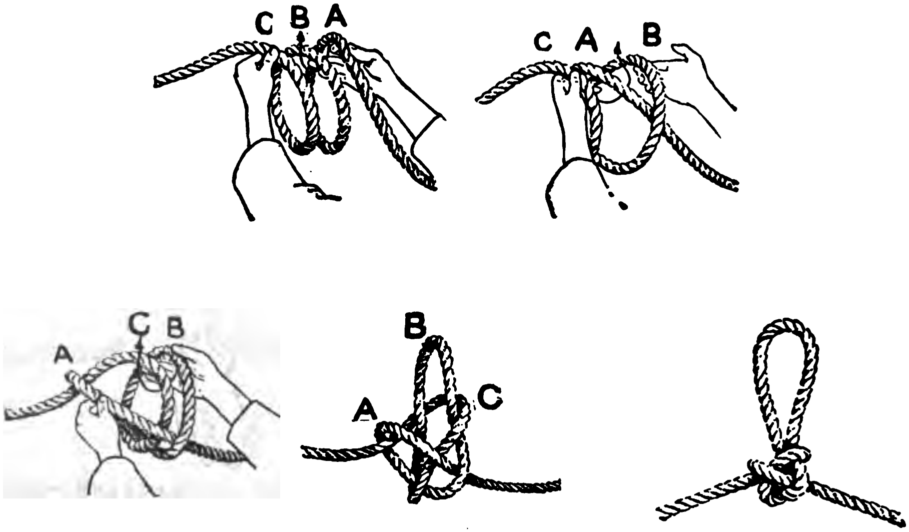


FIGS. 6,001 and 6,002.—Cat's paw. Form a bight in the rope, grasp the sides of the bight, as shown in fig. 6,001, thus forming two loops, twist each loop a full turn in the direction indicated by the arrows, and hang the loops on the hook as in fig. 6,002. The cat's paw provides a double rope where wear comes, and permits a load to be carried on either end of the rope.

FIGS. 6,003 and 6,004.—Taut line or rolling hitch. Wrap the new rope two full turns around the taut one, progressing in a direction away from the load as in fig. 6,003. Pass the end up over the wrapping, draw it firmly, and take one or two half hitches about the taut rope between the wrapping and the load, as indicated by the arrow in fig. 6,003 and as shown in fig. 6,004. The hitch will not hold unless the wrapping and the half hitch are pulled up securely in the first place and are tightened as the strain is put on the new rope. The taut line hitch is useful on many occasions when it is necessary to attach a rope to another rope that is supporting a load and that therefore cannot be bent. For instance, if a strand break, a new rope must be attached to the rope above the break; or if in hauling with block and tackle on a rope to raise a load the tackle be pulled together without getting the load high enough, a new rope must be attached to the taut one near the load in order to support it temporarily and to allow the tackle to be extended and reattached to the pull rope farther up.







FIGS. 6,005 to 6,009.—*Farmer's loop. Form two round turns and hold them as shown in fig. 6,005, thus bringing side by side three ropes, A, B and C. Pass A, under B, and up between B and C, as indicated by the arrow in fig. 6,005, and as shown in fig. 6,006. Pass C under A, as indicated by the arrow in fig. 6,006 and as shown in fig. 6,007. Pass B under C, as indicated by the arrow in fig. 6,007, and as shown in fig. 6,008, pull B, out to form the loop and tighten the knot to the condition shown in fig. 6,009. ***The farmer's loop*** is secure, quickly tied without access to the ends of the rope and capable of being untied after having been drawn tightly.

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*NOTE.—Attributed by Howard W. Riley to a farmer at the Genesee Fair at Batavia, N. Y., in 1910.

Treatment of Rope Ends.—The process of building up a rope from strands is called ***laying a rope***, and so twisting together strands that have become untwisted is called ***relaying***, the latter process being shown in fig. 6,010.

Whipping consists in binding the end of a rope with twine to prevent it untwisting.

Ropes that are to be passed through pulley blocks, or like halter ropes, through small holes, should be finished in this way. A method of doing this so that both ends of the twine are fastened by tucking under the whipping is shown in figs. 6,017 to 6,021.

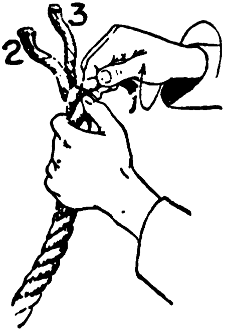
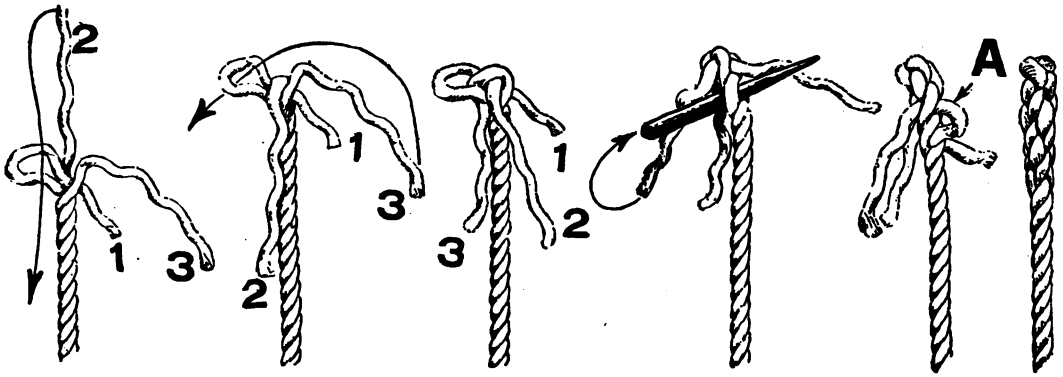


FIG. 6,010.—Relaying: In performing this operation, the rope is held in the left hand, and strand No. 1 is twisted up tightly by turning the right hand as indicated by the arrow around the wrist. This strand is then pulled down snugly into its place in the rope and is held there by pressing the left thumb on the point X. The rope should not be turned in the left hand. The next step is to grasp strand No. 2, twist it up tightly, lay it in snugly above No. 1, holding it with the left thumb by pressing on a point on No. 2 just above the point X, and on the same side of the rope. The left thumb should not work around the rope, but should move straight up the same side. Strand No. 3, is treated as was No. 2 and then No. 1 is in place to be laid in above No. 3. This process is repeated until the end of the rope is reached and it should result in the return of the rope to its original condition provided the strands themselves be not too badly untwisted; in the latter event it is cheaper to cut off the rope than to try to relay it.

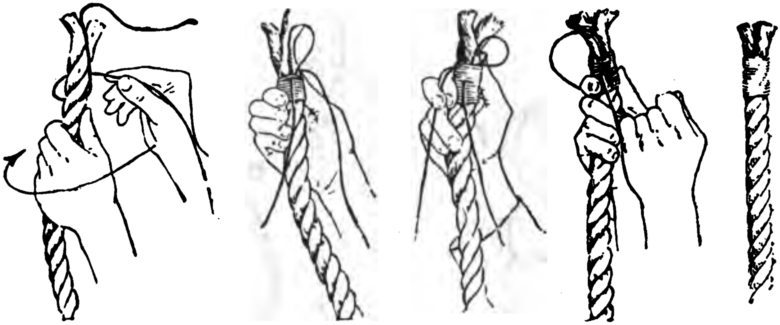
Crowning.—This is a neat, secure and permanent method of fastening the strands of a rope when a slight enlargement of the end is not an objection. Figs. 6,011 to 6,016 show how this is done.



FIGS. 6,011 to 6,016.—Crowning. Unlay the rope from five to ten inches more, according to size. Hold the rope in the left hand with the loose strands up. Select as No. 1, the strand on the left. Lay the strand across the end of the rope and between the other two strands, leaving an open bight projecting to the left as in fig. 6,011. Bring the rear strand, No. 2, forward and down over No. 1, as indicated by the arrow, fig. 6,011, into the position shown in fig. 6,012. Strand No. 3 now goes over No. 2 and down through the bight left in No. 1, as indicated by arrow in fig. 6,012, into the position shown in fig. 6,013. Pull the crown down tightly. Now proceed to splice back the loose ends. Each one is to pass over the nearest strand of the main rope and under the one beyond in a direction diagonally to the right, which is approximately at right angles to the strands of the rope. For the work procure a ***marline spike*** or smooth, round hardwood stick, pointed at one end and rounded at the other. With this instrument raise a strand of the rope close to where the loose ends project, and in the hole thus made insert the end of the proper loose strand as indicated by the arrow in fig. 6,014. Draw it down firmly. This process is called tucking the strand. Raise the strand of the rope next beyond and tuck the next loose strand under it. Then tuck the third strand. Draw all down securely. The loose strands should be given two or three more tucks, each strand receiving only one tuck at a time. As the strands are drawn down into place they tend to twist and kink. This tight twisting causes the tucked strand to stand out from the main rope and makes the splicing bulky. In order to prevent this, just before the strand is pulled into place untwist it at point A, fig. 6,015, and hold down about an inch of the loosened strand with the left thumb. Now draw down all of the strand not held by the thumb. A kink will form which must be drawn through, leaving the loosened strand that was held by the thumb to spread out in a thin band against the main rope. By cutting out some of the material of each strand after each tuck, the splice may be neatly tapered into the main rope, as shown in fig. 6,016. Do not cut the ends of the strands too close to the rope, as they are likely to draw back with use and become untucked. With a smooth round stick pound the splice down solid, and roll it on the floor under the foot.

Emergency Trip Sling.—It is sometimes desirable to use a sling that can be tripped, and the load dropped, without slacking up on the hoisting rope as is done with a regular trip sling for hay. If such a sling be not at hand, a substitute may be made as follows:

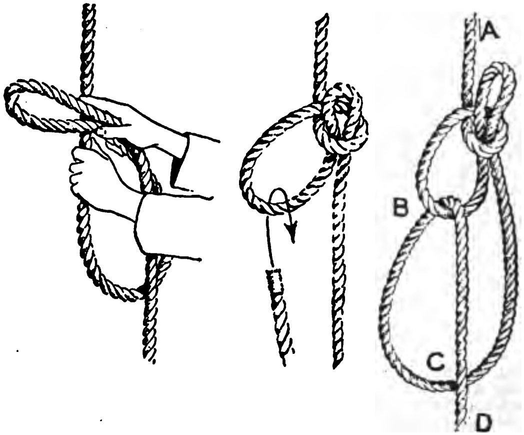
Procure a piece of rope of sufficient length, splice or tie the ends together to make it endless, draw the loop out long, and lay on it the material to be raised. Pull the sling up around the load and lay one end of the sling on the double ropes of the other end, as is done in fig. 5,944. Throw a half hitch over the first end, as shown in fig. 5,945, getting the hitch as near the load as possible and at the same time leaving the end A only long enough to hold. In this case the two ropes extending upward in fig. 5,945 would be joined, forming a bight. Into this bight fasten the hoisting rope and begin hoisting gradually, watching the hitch to see that it becomes properly set.



FIGS 6,017 to 6,021.—Whipping the end of a rope. *To whip:* Unfray one strand of the rope back to the point where the whipping is to begin. Under this strand lay the twine, leaving the end eight or ten inches long as shown in fig. 6,017 and the relay then strand into the rope, keeping it twisted up tightly, and pulled hard down into its place as directed for relaying. If an especially secure whipping is to be made, the twine may be tied about the strand under which it is tucked; usually however, this is not necessary. Whip the long end of the twine around both the rope and the short end of the twine, being careful to pull it up tightly and to leave no vacant spaces between turns. When about half the desired distance is covered, bend back the short end of the twine so as to form a bight extending out beyond the end of the rope and begin whipping over both sides of the bight as shown in fig. 6,018. Continue whipping as far as desired and then pass the long end of the twine as closely as possible. Figs. 6,019 and 6,020 show steps in the process and fig. 6,021 the completed result.

If a trip rope be fastened at the point held by the left hand in fig. 5,945, the hitch may be tripped by a sharp pull toward the right. It must be remembered that this is only an emergency hitch and, while quite secure when properly set, it will give way if not so set. Therefore it is necessary to keep from beneath the load.

Care of Ropes.—Hemp is easily rotted by the influence of damp; hence, if the ropes have been used in the rain or allowed to get into water, they must be hung up to dry. A beam within a shed, some eight or ten feet above ground, is most convenient for this purpose, the rope being passed over it from one side to another, and hanging down in loose festoons on each side *well clear of the ground.* This facilitates the circulation of the air around each part of the rope. *On no account* should a rope be coiled up when wet, as the internal covered parts absorb all the moisture and quickly rot.

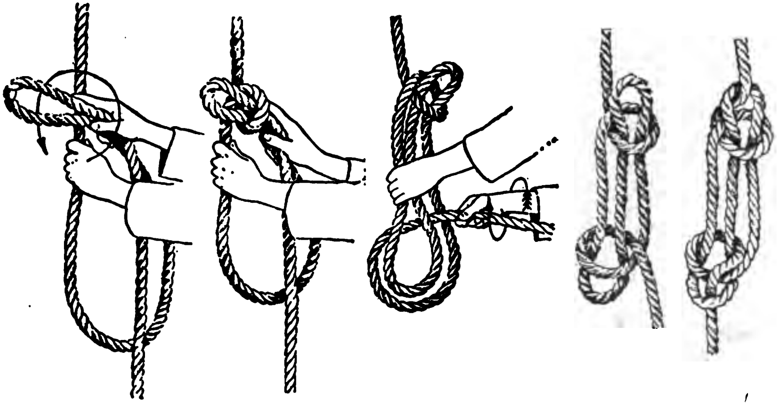


FIGS. 6,022 to 6,024.—Rope tackle. There are times when a temporary substitute for a tackle block would be found most useful, as, for example, in drawing down a rope over a load of hay to hold it without a pole. The rope tackle shown in fig. 6,024 forms such a temporary substitute. Make a bight in the rope and throw a half hitch over it, as described for the sheepshank and as here shown. Through the hanging loop thus formed pass the lower end of the rope, as indicated by the arrow in fig. 6,023. This gives the finished tackle as shown in fig. 6,024. If, now in the example cited above, the rope A (fig. 6,024) come from over the load of hay and the bight C, is caught over the end of the reach or some other convenient part of the wagon, by pulling on rope D, we can cause the rope to pull on loop B, which will act as a tackle block and will greatly increase the pull on A. Both sides of the loop C, must pull on the tackle above, otherwise the half hitch will pull out. The rope slides and chafes badly at B, and somewhat at C, so this tackle should not be made up frequently in the same place in the rope. It is intended for emergency use only.

Constant inspection is necessary, as unlooked for damage may be occasioned by the parting of a rope. A good method of inspecting the inside fibres is by partially untwisting the strands by moving each hand in opposite directions as they hold the rope; this gives an opportunity of examining the under side of the strands.

The strain and chafing cause rupture of the fibres, which must be seen to. Much of this trouble may be obviated in the case of standing ropes by using "parcelling," or chafing-gear, of rags, marline or leather bound around the rope to protect it.

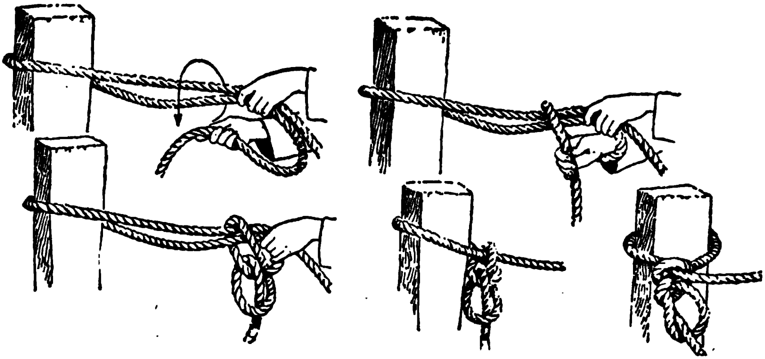
Always suspect a rope that has lain in a warm place, such as a boiler house. It may have "perished" and is not trustworthy.



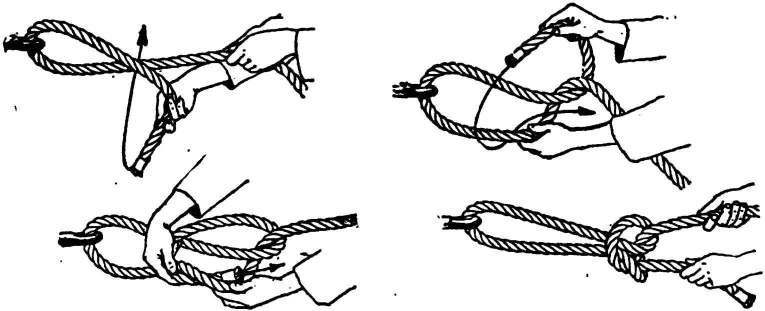
FIGS. 6,025 to 6,029.—**Sheepshank.** Form a bight and lay it against the rope leaving below it a second bight or loop as long as is needful for reducing the rope to the required length as in fig. 6,025. Holding the first bight with the right hand, with the left hand throw a half hitch around it as indicated by the arrow in fig. 6,025 and as shown in fig. 6,026. With the left hand grasp the sides of the second bight and with the right hand throw a half hitch of the rope over this bight by turning the right wrist, as indicated by the arrow in fig. 6,027, and as shown in the finished sheepshank in fig. 6,028. If it be desired to shorten the rope permanently, the ends may be passed through the first and second bights, as shown in fig. 6,029. The sheepshank *is used for* shortening a rope, is made quickly and without access to the ends. It may be tied in a rope and the rope may then be cut at the end of one of the two bights or along the central part in fig. 6,028, after which a strain may safely be put on the rope just as if it were not cut. It is said that this fact is utilized by steeple climbers. who, before lowering themselves by ropes from towers where they have been at work, make a sheepshank near the upper end of the rope, cut it as described above, lower themselves to the ground, and then loosen the sheepshank by shaking it, when the cut rope falls to the ground leaving only a short end up on the tower.

Ropes that have to be exposed to wet are rendered more durable by coating the yarn with Archangel tar in the process of making. This, however, reduces the strength of the rope by one-fourth.

It may be advisable to state here that rope makers generally specify all their manufactures in terms of *their circumference*, and the various formulæ for weight and strength are all calculated from that dimension.



FIGS. 6,030 to 6,034.—Hitching tie. Pass the rope around the post from left to right, thus forming a bight. Grasp both sides of the bight in the left hand, and with the right hand throw the short end across the ropes in front of the left hand as indicated by the arrow in fig. 6,030, thus forming a second bight below the left hand. Pass the right hand through this second bight, as in fig. 6,031, and pull the rope back through it to form a third bight, down through which the end of the rope is passed as shown in fig. 6,032. Pull the knot up tightly. There is a right way and a wrong way to leave this tie when hitching to a plain post without a groove, ring, or crossbar to keep the rope from slipping down. If the knot be twisted around to the right of the post, as in fig. 6,033, a pull on the tie rope will draw the rope tightly about the post and will thus prevent it slipping down; if, on the other hand, he knot be at the left, as in fig. 6,034, a pull will not tighten it and it will slip down.



FIGS. 6,035 to 6,038.—Halter tie. Pass the end of the rope upward through the ring, then downward on the left of the long rope, grasping it with the right hand and holding the long rope with the left hand as shown in fig. 6,035. Draw the end to the right and upward as indicated by the arrow in fig. 6,035, thus supporting the long rope as shown in fig. 6,036. Now pass the end of the rope over, under, and again over the long rope, as indicated by the arrow in fig. 6,036 and as shown in fig. 6,037. Draw the end through, as in fig. 6,038, and set the knot *by pulling first on the short end.* This is important. If the long rope be pulled first and the kinks in it be straightened out, the tie forms a slip knot, being simply two half hitches around the rope, as in fig. 5,957. The halter tie is preferred by some persons to the hitching tie just described, for use in hitching or in tying the halter rope in the stall. If properly set, it is secure and may be used in some cases in place of the underhand bowline knot. The halter tie should never be used around a horse's neck, because if the tie be not set up correctly it forms a slip knot and its use might result in strangulation of the animal.

Rope Transmission.—There are two distinct systems of rope drive,

1. The multiple or English system.
2. The continuous or American system.

Each of these has its advocates, certain sections of the country adopting one and condemning the other.

The mutliple system is the simpler and consists of one or more independent ropes, running side by side in the grooves of the pulleys.

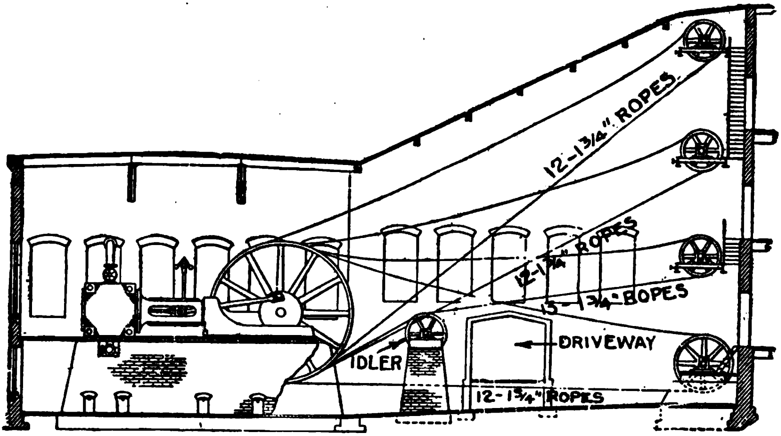


FIG. 6,039.—Multiple drive for cotton mill, transmitting power from one main driving pulley to several shafts located in different flows. Each rope transmission may consist of one or more independent ropes, according to the amount of power to be transmitted.

This system is especially adopted to the transmission of large powers, and gives the very best results for drives protected from the weather, when the shafts are parallel or nearly so, and where the drive is sufficiently off the vertical to prevent ropes, when slack, leaving the grooves of the lower sheave. With this system the drive has the greatest security against breakdowns, because of the extreme unlikelihood of more than one rope giving way at the same time.

When a failure does occur, the individual rope may be removed and repaired at some convenient time.

Again power may be more easily carried to the different floors of a mill; the amount of power transmitted may be more readily increased by the addition of new ropes; the rope always bending in the same direction, has longer life than in the continuous system; finally it is cheaper to install and maintain.

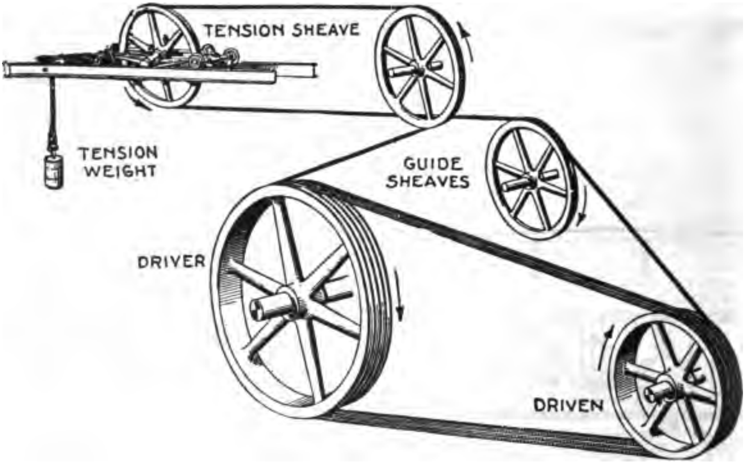


FIG. 6,040.—Continuous drive; I, tension taken from driver.

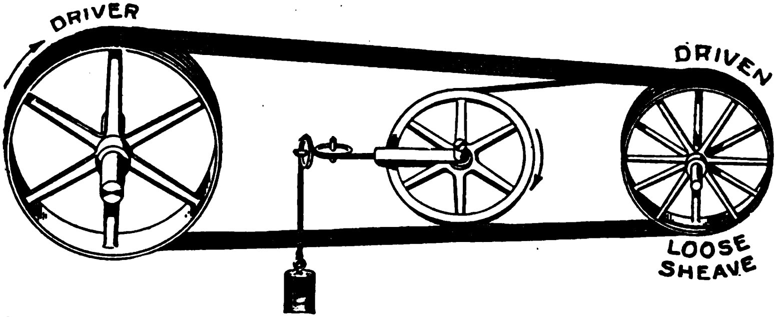


FIG. 6,041.—Continuous drive; II, tension taken from driver.

In the continuous system, one rope is wound around the driving and driven pulleys several times. With this system it is necessary by some device to conduct the rope from an outside groove of the delivering, to the opposite outside groove of the receiving pulley, this transfer being accomplished by means of a travelling tension carriage or "jockey" whose office is to produce a uniform tension throughout the rope, and is so arranged as to travel back and forth, automatically regulating the slack which may occur from stretch in rope, inequalities, of lead, etc.

The slack should be taken care of where it accumulates which is on the slack side of drive just off the driven pulley.

This may be done in two ways: 1, by conducting the rope from an outside groove of the driver to the tension sheave, and, after passing around it, is returned to the opposite outside groove of the driver pulley; 2, by taking it from the driver, the rope being led from an outside groove which is a loose or independent sheave, to the tension sheave and thence returned to the opposite outside groove of the driver pulley. These two methods admit of considerable variation.

The continuous system is especially adapted to vertical and quarter turn drives, where shafts are at an angle to each other, where rope is exposed to the weather, and in any special case of complicated transmission.

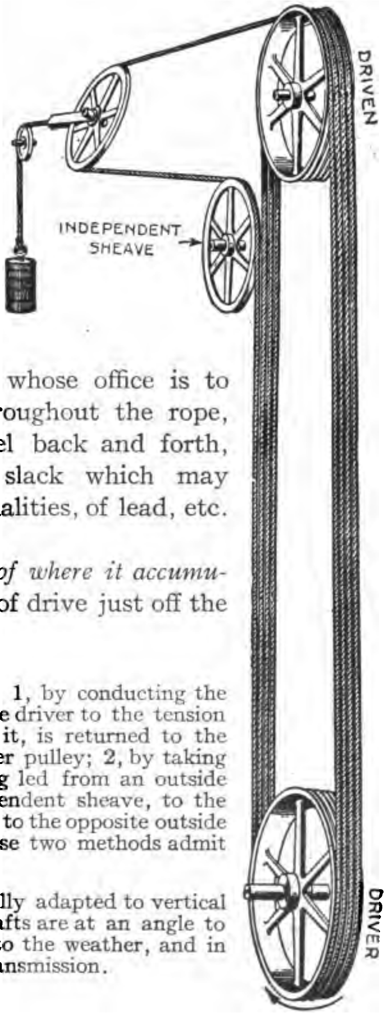


FIG. 6,042.—Continuous vertical drive; III, tension taken from driver.

In the compound wrap system both the driving and driven pulleys have accompanying idlers. The rope is wrapped several times around the driver and its idler, thence conducted to the driven in one or more parts, and there wrapped as before around the driven and its accompanying idler as shown in fig. 6,043.

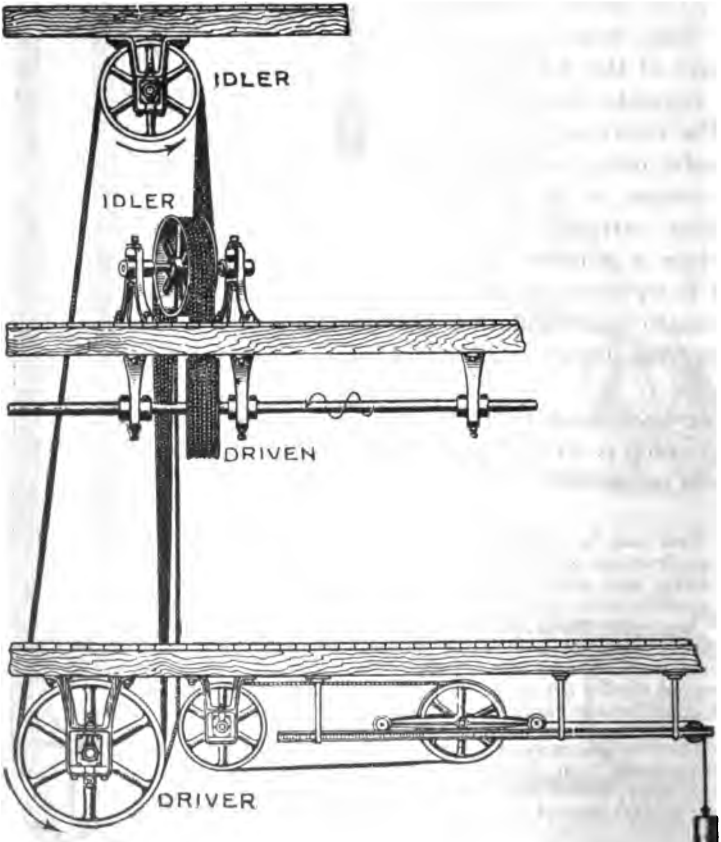
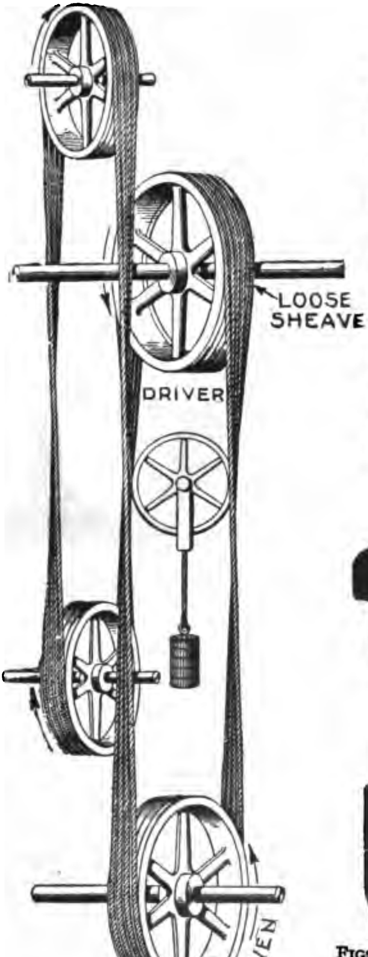
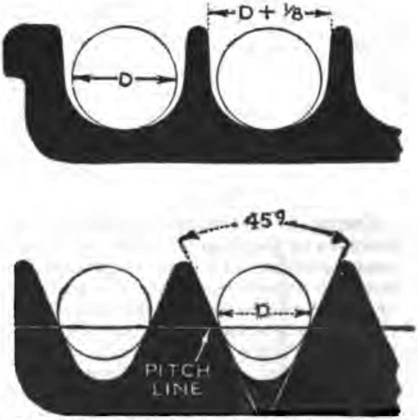


FIG. 6,043.—Compound wrap system.



Rope, Sheaves and Grooves.—The pulleys or sheaves are second in importance only to the rope itself. To prevent undue wear of the rope, the sheave should be made as large as practicable, and in practice the minimum diameter should be not less than thirty-six times that of the rope; forty diameters is better. The use of large sheaves not only increases the life of the rope but the larger contact surface increases the transmitting capacity.



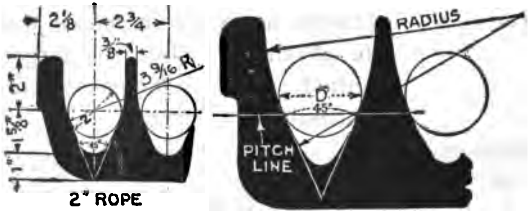
FIGS. 6,045 and 6,046.—Forms of working and idle grooves generally adopted for the continuous system.

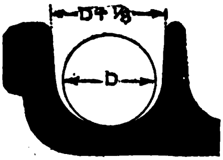
FIG. 6,044.—Quarter turn drive; tension taken from and returned to driver or loose sheave.

In regard to the shape of the groove all driving and driven sheaves should be turned with a wedge or V-shape groove, of such size and depth that the rope can never touch the bottom. In practice the best results are obtained with an angle of 45°.

Idler or carrier pulleys are provided with V-shaped grooves.

Since in the continuous system the rope is kept taut, it is not so apt to jump from the groove which can therefore be made more shallow than for the multiple system, in fact many drives are now running where the rope extends beyond the flanges of the grooves.





Figs. 6,047 and 6,048.—Two styles of working groove. It will be noted that while the angle of groove in both figures is 45°, the sides of the groove in fig. 6,047 are straight, and those in fig. 6,049 are arcs of circles, having radii proportional to the diameter of the ropes to be used. The sides are thus curved to assure the rope revolving in the groove, a condition sought by the practical mill man as it causes uniform wear.

Fig. 6,049.—Groove for idlers as used in the multiple system.

Owing to the nature of the continuous system, the rope necessarily revolves in the groove. In the construction of a rope sheave, special care must be taken in turning the grooves to secure the same pitch line in each in order to avoid *creeping* of the rope. In badly turned grooves this slack or creep can be noticed to travel from one groove to another; while in the multiple system irregularities in pitch line are shown by certain ropes being taut upon the slack side and slack upon the driving. This feature however may exist from other causes than variations in pitch as a new rope which is placed upon a drive with older ones, being larger in diameter, will sometimes run in this manner for a few days, until stretched to the same diameter as its companions.

It is essential that the grooves, be well polished as the slightest roughness will quickly destroy the rope.

Transmission Rope.—To facilitate computation as well as for convenient information for transmission rope users. the following table is given:

Properties of Transmission Rope

Diameter of Rope	Square of Diameter	Approx. Shipping Wgt. per ft.	Breaking Strength	Maximum Allowable Tension	Length of Splice, feet			Smallest Diam. of Sheaves, inches	Maximum Number of Revolutions per Minute
					3 Strands	4 Strands	6 Strands		
¾	5625	.21	3,950	112	6	8		28	760
⅞	7656	27	5,400	153	6	8		32	650
1	1	.36	7,000	200	7	10	14	36	570
1⅛	1 2656	45	8,900	253	7	10	16	40	510
1¼	1 5625	.56	10,900	312	7	10	16	46	460
1⅜	1 8906	.68	13,200	378	8	12	16	50	415
1½	2.25	80	15,700	450	8	12	18	54	380
1⅝	2.6406	92	18,500	528	8	12	18	60	344
1¾	3.0625	1 08	21,400	612	8	12	18	64	330
2	4	1 40	28,000	800	9	14	20	72	290
2¼	5 0625	1 80	35,400	1,012	9	14	20	82	255
2½	6 25	2 20	43,700	1,250	10	16	22	90	230

Weight of rope = .34 × diam.^{2}
Breaking strength = 7,000 × diam.^{2}
Maximum tension = 200 × diam.^{2}

Diam. smallest
practicable pulley = 36 × diam.
Velocity of rope (assumed) = 5,400 ft. per min.

Horse Power.—For convenience in determining the horse power that single ropes of different diameters will transmit, the following table is given.

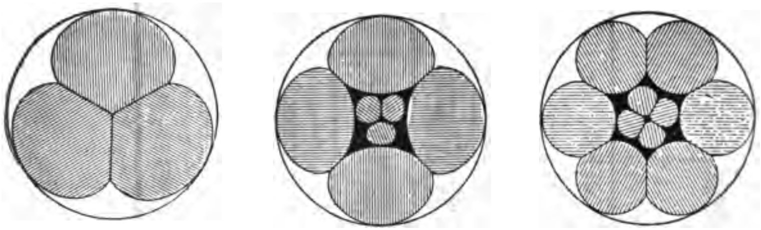
Horse Power of Manila Rope

Diameter of Rope	Velocity, Feet per Minute										
	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000
¾	2.3	3.3	4.3	5.2	6.0	6.6	7.2	7.3	7 4	7.3	6.9
⅞	3.0	4.5	5.9	7.0	8.2	9.0	9.6	9.8	10.0	9.6	9.0
1	4.0	5.9	7.7	9.2	10.6	11.8	12.7	12.9	13.0	12.7	12.0
1⅛	5.0	7.5	9 7	11 6	13.5	14.9	16.0	16.3	16.7	16.5	15.3
1¼	6.3	9 1	12.0	14 3	16 7	18.5	20.0	20.2	20.7	20.1	18.9
1⅜	7.5	10.8	14.4	17 4	20.0	22.1	23 7	24.5	24.6	24.0	22.3
1½	9.0	13.5	17.4	20.7	23.0	26.3	28 7	29.0	29.5	28.6	26.7
1⅝	10.5	15.5	20.1	24.3	27.9	30.8	32.9	34 1	34.3	33.3	31.0
1¾	12.3	18.0	23.6	28.2	32.7	36.4	38.5	39.4	40.5	38.7	36.0
2	16.0	23.2	30.6	36.8	42.5	46.7	50.0	51.7	52.8	50.6	47.3
2¼	20 0	29.6	38.6	46.6	53.0	59.2	63.6	65.8	66.3	64.4	60.3
2½	25.0	36.6	47.7	57.5	66.0	71.2	78 0	80.0	81.0	79.0	73.8

Sag.—For drives where shafts are at different elevations, the sag will have to be worked out in each particular case, but for horizontal drives the approximate sag may be determined by the following formula:

$$\text{Sag on driving side} = \frac{\text{weight} \times (\text{distance bet. sheaves})^2}{8 \times \text{maximum tension}} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The assumed tension is taken as $200 \times \text{diam.}^2$

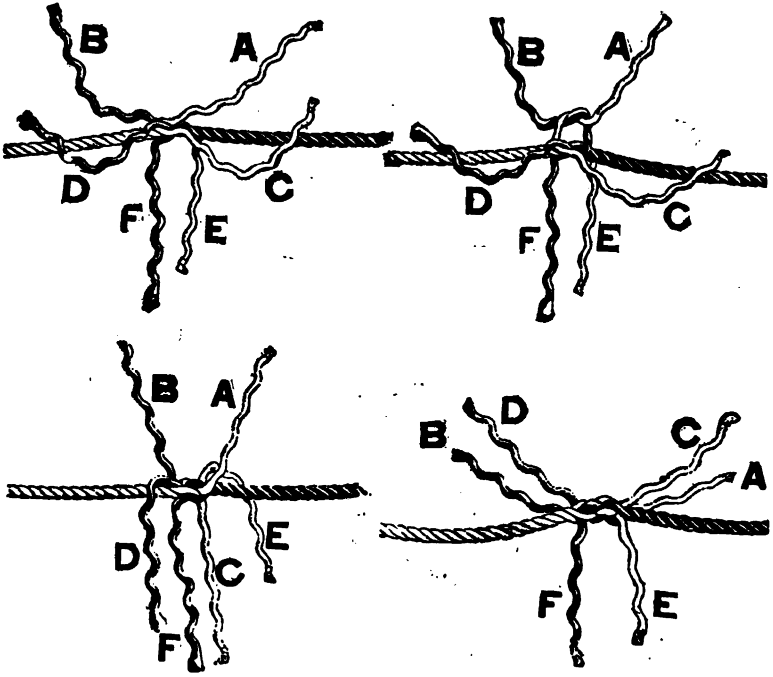


Figs. 6,050 to 6,052.—Manila transmission rope. It is made in three, four and six stands as shown from the fibre of the *abaca* plant of the Philippine Islands. For small drives under ⅞ in., or where the rope is subject to much bending, the 3 strand rope is suitable; for large drives the 4 or 6 strand with the urn core should be used.

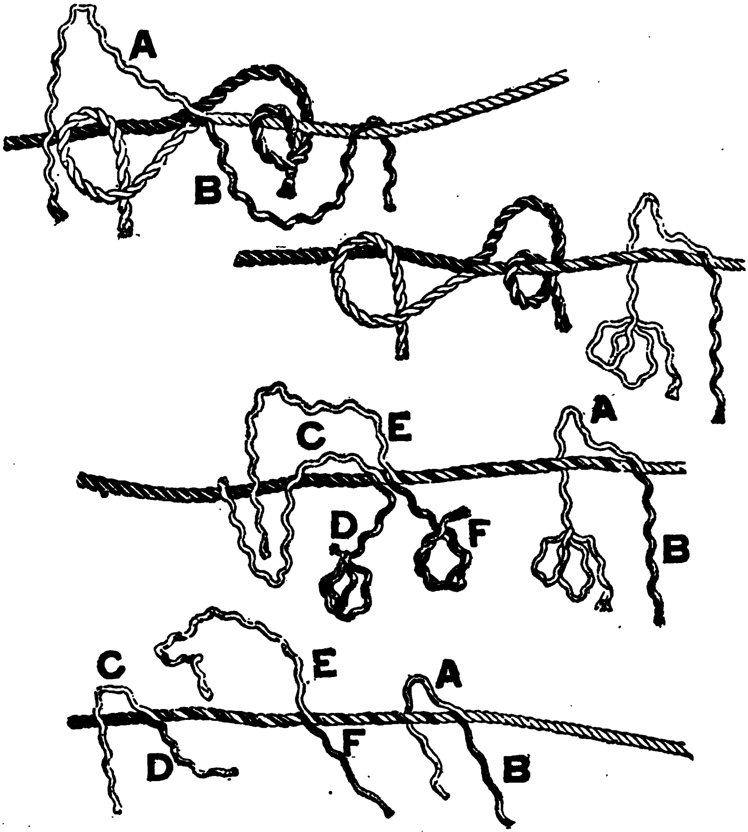
The following table gives the sag on driving and slack sides:

Sag

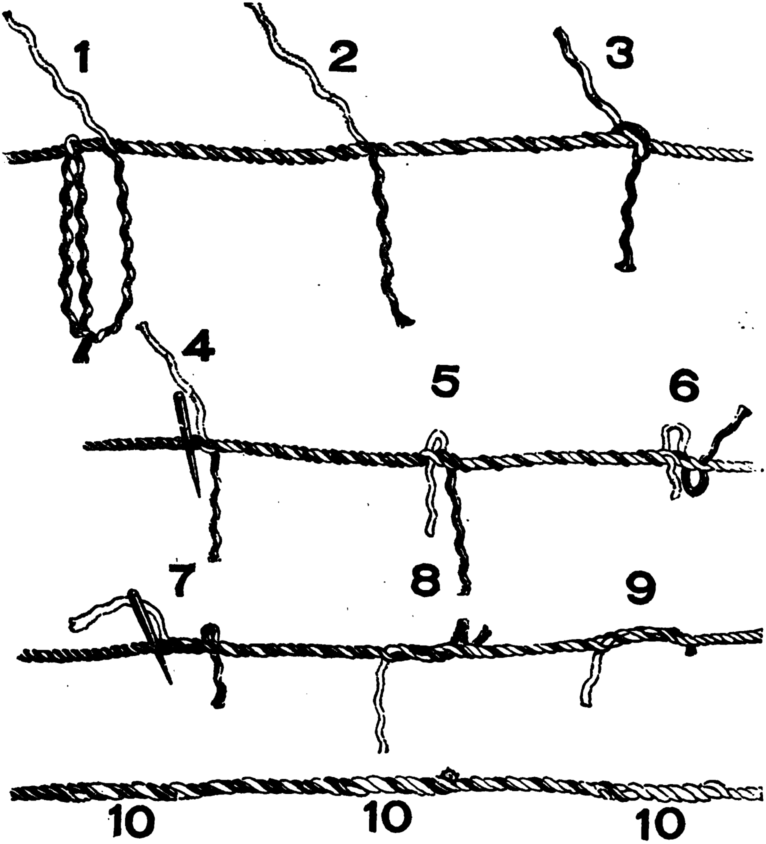
Distance between Pulleys, Feet	Sag on Driving Side, All Speeds, Feet	Sag on Slack Side				
		Velocity, Feet per Minute				
		3,000	4,000	4.500	5,000	5,500
30	.19	.45	.39	.36	.33	.30
40	.34	.80	.69	.64	.59	.53
50	.53	1.2	1.1	1.0	.92	.84
60	.76	1.8	1.7	1.4	1.3	1.2
70	1.0	2.4	2.1	1.9	1.7	1.6
80	1.4	3.2	2.9	2.5	2.3	2.1
90	1.7	4.0	3.5	3.2	3.0	2.7
100	2.1	5.0	4.3	4.0	3.7	3.3
120	3.0	7.2	6.2	5.7	5.3	4.8
140	4.1	9.9	8.5	7.8	7.2	6.6
160	5.4	12.9	11.1	10.2	9.5	8.6



FIGS. 6,053 to 6,056*a*.—Short splice. Untwist the strands at one end of each rope for a length of six to fifteen inches or more, depending on the size of the rope. Butt these ends tightly together as in fig. 6,053, laying each strand of each end between two strands from the other end, as strand A, is between strands B and D; C between D and F, and so on. This process is called *locking the strands*. With a simple overhand knot, tie each strand of one rope to the corresponding strand of the other rope, as A and B in fig. 6,054. Note particularly the way in which this knot is tied. The black strand just beyond the white one is the corresponding one for that white strand, as A corresponds to B while D does not. The knots being all pulled down, the splice appears as in fig. 6,055. Give each strand of the left rope one tuck toward the right, as described for splicing back the ends in crowning (fig. 6,055). The splice will now appear as shown in fig. 6,056. Tuck each of the other three strands once to the left. The splice will hold if carried no farther, and therefore if only a rough job is desired the strands may now be cut about one quarter or even one half inch from the rope. If a nicely finished job be desired, finished the splice as directed for fig. 6,056 and 6,056*a* giving the result shown in fig. 6,056*a*. As all the strands of one rope are woven into the other rope at one place, the rope at that place is six strands thick and the splice is of necessity considerably larger than the original rope, hence short splice will not run through pulley blocks.



Figs. 6,058 to 6,064.—Long splice. *I, three strand rope.* Unlay only one strand of each rope; 18 ins. for ⅜ in. rope; 24 ins. for ½ in. rope; 30 ins. for ¾ rope; 36 ins. for 1 in. rope, etc. Lock and draw the end of the ropes tight together as in fig. 6,057, having the single strands A and B side by side. Taking care not to let the ends of the ropes separate, unlay strand A, give its rope one turn and follow it with strand B. Keep B twisted up tightly and pulled down firmly into its place (as explained for relaying fig. 6,010). Continue until only six to 9 ins. of strand B is left out (fig. 6,058) depending on the size of the rope. Now untwist the two pairs of strands left at the center and lock them as in fig. 6,059, C, between D and F, and F, between C and E. Unlay toward the left strand D, and follow it with C, as was done toward the right with strands A and B. Do not mistake and unlay F, instead of D and follow it with C; this will cause trouble if done. Continue until strand C, is only six to nine inches long. The breaks in the strands are now separated as shown in fig. 6,060. Each pair of strands is now to be tied and the end of each strand tucked. Some of the strands will be too long as at 1, fig. 6,061. Cut all strands to the length of the shorter.



FIGS. 6,057 to 6,064.—*Text continued.*

Arrange each pair so that the strand from the left is in front of the strand from the right; that is, arrange the strands so they cannot untwist from the rope without first uncrossing (see 2, fig. 6,061). Tie an overhand knot, as at 3, fig. 6,061, and pull it down tightly into the rope. Each strand is now tucked, as at 4, 5, and 6, fig. 6,062, in the same way as for crowning (figs. 6,014 to 6,016). At 6 (fig. 6,062), untwist each strand before pulling down, as for A, in fig. 6,015. Tuck each strand twice more (see 7 and 8, fig. 6,063), tapering the ends if desired, and cut the end one quarter inch long (as at 9, fig. 6,064). With a round stick pound down each part of the splice and roll it on the floor under the foot. ***The long splice*** is used to secure a joint not so bulky as the short splice, and one that will run through pulley blocks, the strands are untwisted for a longer distance and the splice is so made that each pair of strands is joined in a separate place in the rope instead of all at one place. In a three strand rope the greatest number of strands at any place in the splice is four instead of six as in a shut splice.

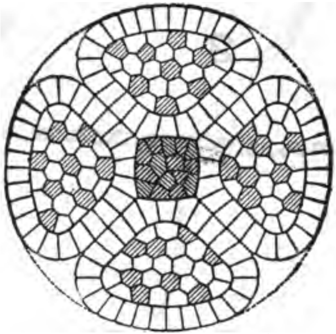


Fig. 6,065.—American transmission rope showing lubricated and cover yarns.

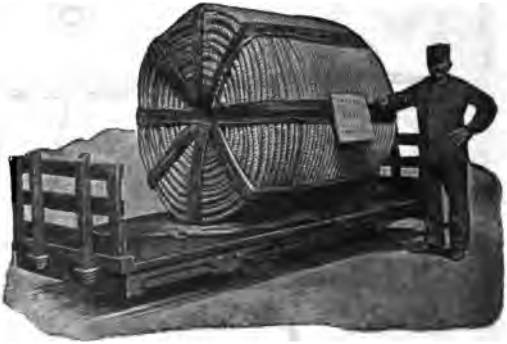
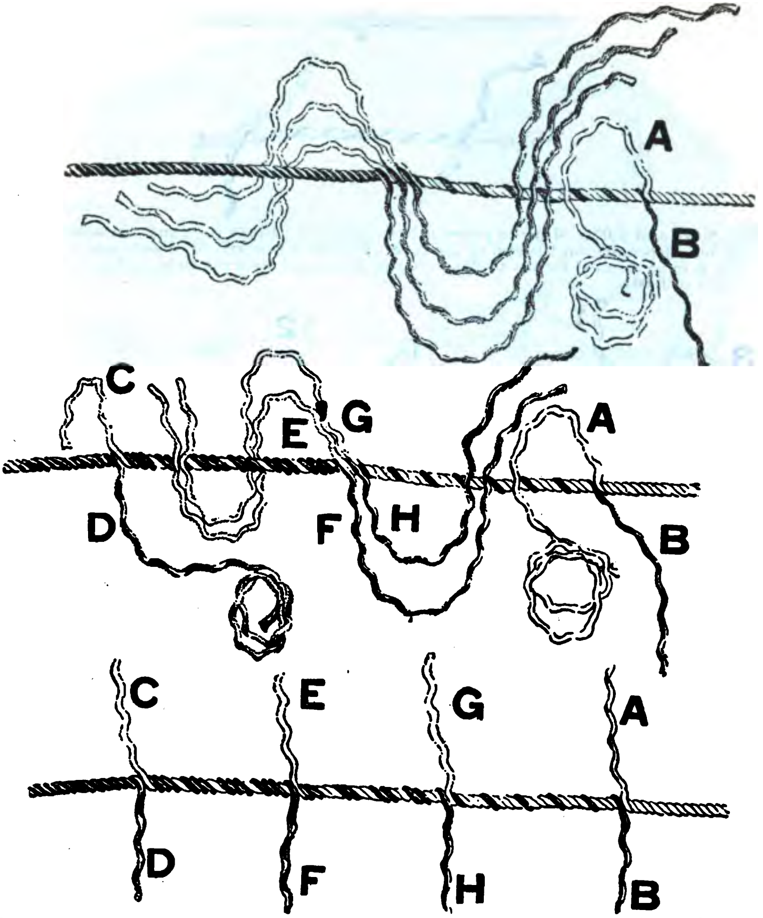


Fig. 6,066.—6,000 foot coil of 1½ in. diameter American transmission rope, made in one continuous length without splice.

NOTE.—***Manila transmission rope*** is made from the fibre of the "Abaca Plant" which grows only in the Philippine Islands. The trunk of this plant, resembling the banana tree, is closely enfolded by long leaves, and from these leaves is procured the fibre so wonderfully suited to the requirements of rope. This fibre varies in the length from six to twelve feet and some leaves attain a length of eighteen feet. Its tensile strength is remarkable, official tests at Watertown, Mass., have proved it to be in excess of 50,000 pounds per sq. in. This great strength, however, is shown only when the fibres are subjected to a straightaway or longitudinal strain, transversely, owing to their cellular formation, the fibres are relatively weak. For this reason, in manufacturing transmission ropes, the greatest care is necessary to secure such proportion of twist, in both the yarns and the strands, as to render the rope least vulnerable to crosswise strains, and to the frictional wear and tear resulting from the constant rubbing and grinding of strands against each other while passing over the pulleys. Further, this correct proportion of twist is essential in order to assure the rope maintaining its proper form when put in service. To accomplish this, the fibres when making the yarns are first twisted to the right, next the yarns when making the strands are twisted to the left, and lastly, the strands are twisted together in a right hand direction, to form the finished rope. Transmission rope is made with three, four or six strands, the four and six strand ropes having an inner core or heart, around which the outer strands are laid. For small drives, where the diameter of rope is less than ⅞ inch, or where the rope is subject to much bending, the three-strand rope gives excellent results, lending itself readily to abrupt turns. For the large drives the four and six strands are preferred; being more nearly circular, and of greater cross section, they secure a larger surface of contact in the groove.—*American Mfg. Co.*



Figs. 6,067 to 6,069.—Long splice. *II, four strand rope.* The first steps in making this splice are identical with those shown in figs 6,057 and 6,058. The first strand, however, must be unlaid nine inches or a foot farther than for as plice in a three strand rope. Untwist the strands left at the center and lock them, as in fig. 6,067. Unlay toward the left strand D, and follow it with C, leaving E, F, G and H. at the center (see fig. 6,068). Follow the instructions for this part of the work as given for the three strand splice. Then unlay strand F, toward the left and follow it with E for one third the distance from the center to where strands C and D are left. Run G and H an equal distance toward the right. Cut all the long ends to the length of the shortest strand as in fig. 6,069. The splice is completed as explained for figs. 6,061 to 6,064.

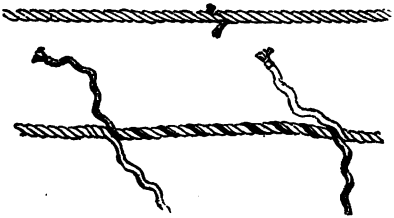
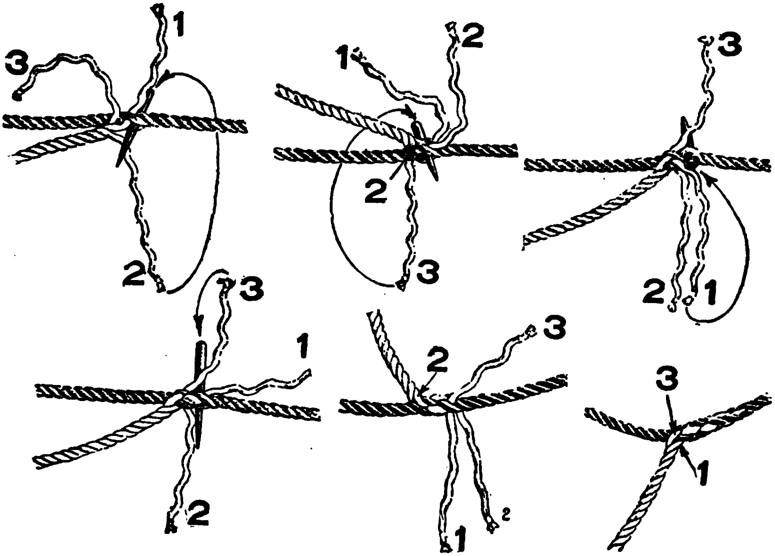


FIG. 6,070 and 6,071.—How to renew a broken strand. Unlay each end of the strand 9 to 18 ins., depending on the size of the rope. Procure a new strand of sufficient length and lay it in as directed for fig. 6,058. Tie the strand and tuck the ends, as directed for figs. 6,061 to 6,064.



FIGS. 6,072 to 6,077.—Eye or side splice for forming an eye or loop in the end of a rope. Untwist the strands of the rope end 6 to 15 ins. or more, depending on the size of the rope. Select as No. 1, the strand that is on the top of the rope and in the middle between the other two strands. Raise a strand on the top of the solid rope and pass No. 1 under it diagonally to the right as in fig. 6,072. Pull it up securely. Turn the two ropes over to the position shown in fig. 6,073. Raise the next strand on this side of the one first raised and tuck No. 2 under it away from the body as in fig. 6,073. When the marline spike is inserted for this tuck, it comes out where strand No. 1 went in, as shown in fig. 6,072. Turn the ropes back to their original position (fig. 6,074). Strand No. 3 is now to be tucked. This strand is inserted at the place where No. 1 comes through, as shown in fig. 6,074; it comes out where No. 2 starts in, as indicated in fig. 6,072 where the spike is shown inserted for tucking No. 3. Pull the splice up firmly and then proceed to splice the ends into the solid rope, as shown in figs. 6,075 to 6,077, in precisely the same manner as was explained for figs. 6,014 to 6,016. Pound the splice and roll it under the foot.

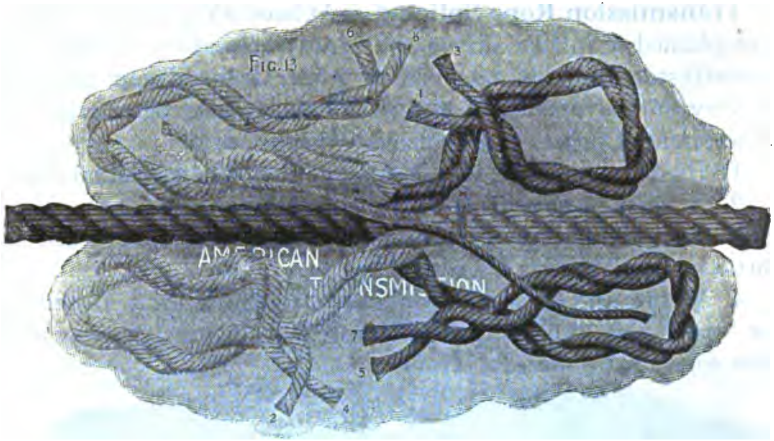


Fig. 6,078.—English Transmission splice; I, The rope is first placed around sheaves, and, with a tackle, stretched and hauled taut. The ends should pass each other from 6 to 7 ft., the passing point being marked with twine on each rope. The rope is then slipped from sheaves and allowed to rest on shafts to give sufficient slack for making splice. Unlay the strands in pairs as far back as the twines, M, M, crotch the four pairs of strands thus opened, cores having been drawn out together on the upper side.

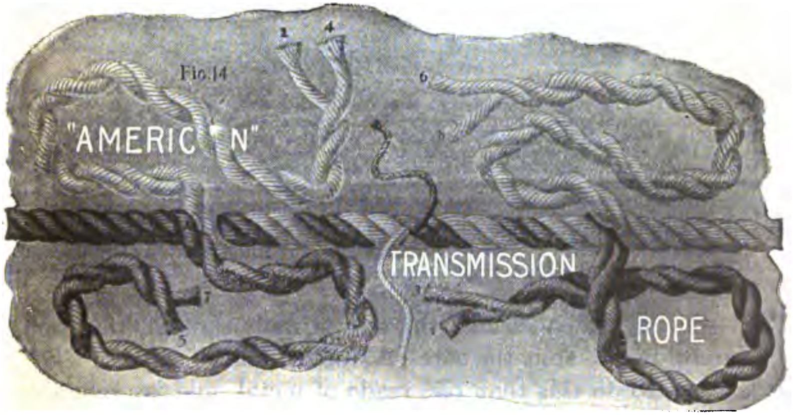


Fig. 6,079.—English transmission splice II.—Having removed marking twine M (shown in fig. 6,078), unlay the two strands 6 and 8, still in pairs, back a distance of two feet, to A, the strands 1 and 3, also in pairs, being carefully laid in their place. Next unlay the strands 5 and 7 in pairs, to A^1, replacing them as before with 2 and 4. The rope is now in the condition shown above.

Transmission Rope Splicing.—At least 95% of the troubles complained of in rope drives are directly caused by bad splicing notwithstanding that to make a proper transmission splice is a very simple operation, the idea having once been grasped. The essential points in a transmission splice are:

1. Its diameter must be the same as that of the original rope.
2. It must be smooth and free from lumps.
3. The original lay of strands and yarns must be disturbed as little as possible.
4. Where the several strands are rejoined, each fastening or "tuck" should be so made as to prevent its wearing away and the rope unstranding.

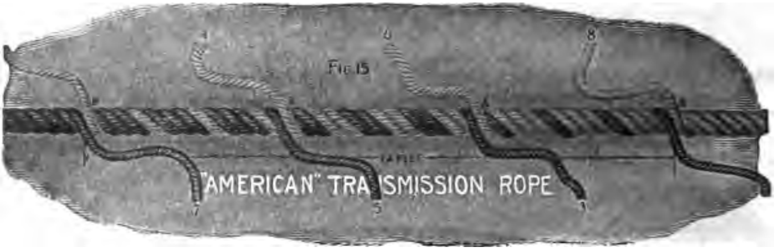


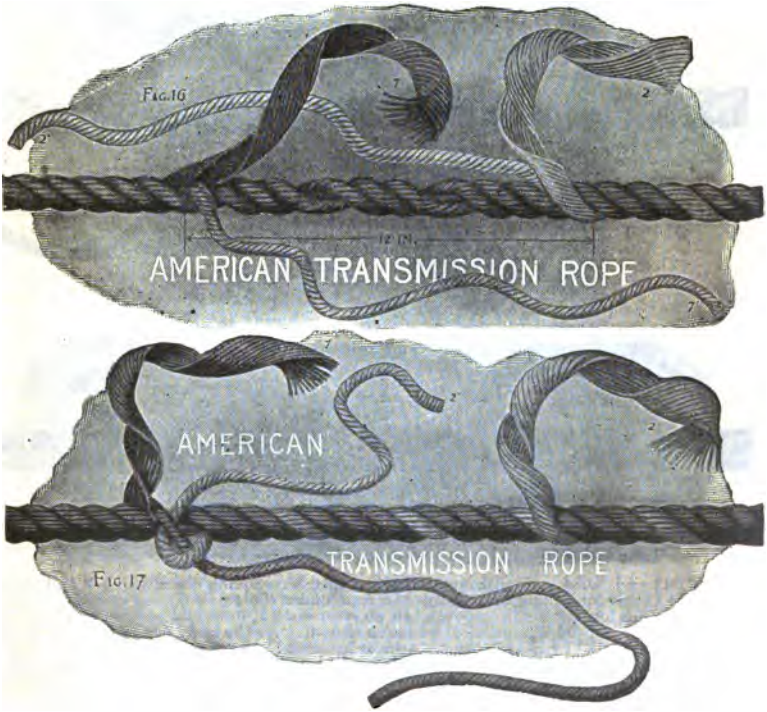
Fig. 6,080.—English transmission splice III. The pair of strands 1 and 3 having been separated, 3 is left at A, as companion for 6, strand 1 being carefully laid in place on strand 8 until they meet at point B. The two pairs of strands 2-4 and 5-7 are now separated and laid in the same manner, care being taken, while thus putting the rope together, that original twist and lay of strand is maintained. The protruding cores are now cut off so that the ends, when pushed back in rope, butt together, the rope now appearing as above. After the eight strands have been cut to convenient working lengths (about 2 ft.), the companion strands are ready to be fastened together and *tucked*.

The English transmission splice is considered the best splice known and is the one here described, the example taken and illustrated in the accompanying cut being a four strand rope 1¾ ins. diam. as spliced on sheaves in the multiple system.

In splicing, when *tucking* the half strands through the rope, be careful not to split the core. A wooden marlin spike or "fid" is less apt to do this than one made of metal, and is preferable for splicing transmission ropes.

In tucking the half strands one about the other, not less than three or more than five turns should be made.

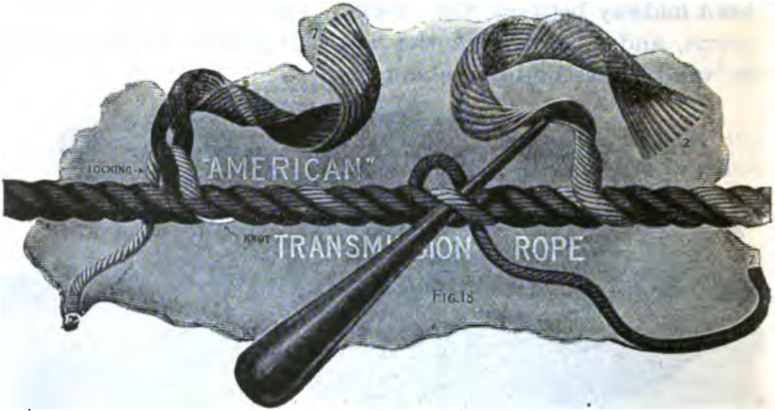
When dividing a strand let the cover half, which is left behind at the lock, contain several more yarns than are in the half strand with which the tuck is to be made, in order that the hand made knots shall not be larger than the original machine laid strand. When tying half strands do not make the first knot midway between the "locks," but tie close to the cover yarns, and securely lock the first half strand before beginning to wind the second one about it.

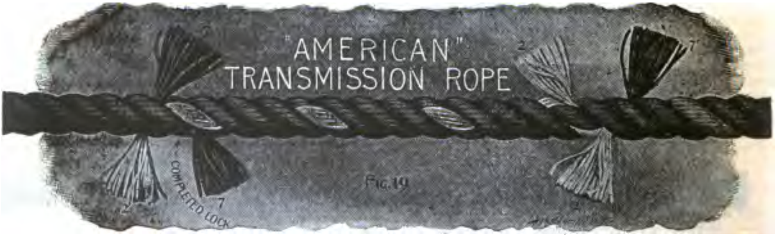


FIGS. 6,081 and 6,082.—English transmission splice IV. The operation of tucking is described for strands 2 and 7, the method being identical for the other three pairs. In fig. 6,081 unlay 2 and 7 for about 12 to 14 ins., divide each strand in half by removing its cover yarns and whip with twine the ends of interior yarns 2′ and 7′. Now, leaving cover 2, relay 2′ until near 7 and 7′, here join with simple knot 2′ and 7′ as in fig. 6,082.

When ropes are to be taken up, ***do not cut out splice***, unless there be ample slack to allow for an entire new one. The English splice, when well made can be "backed out" with very little loss of rope.

Old ropes when taken up should not be spliced on sheaves as taut as when new. When splicing in the Continuous System, do not draw tension carriage to extreme end of track; allow short distance for contraction.





Figs. 6,083 and 6,084.—English transmission splice V. Divide cover yarns 7 and pass 2′ through them, continuing on through the rope under the two adjacent strands, avoiding the core, thus locking 2′ (fig. 6,083). *In no event must 2′ be passed over these or any other strands.* Half strand 7′ must now be taken care of. At the right of the knot made with 2′ and 7′, 2′ is slightly raised with a marlin spike, and 7′ passed or tucked around it two or three times, these two half strands forming in this way a whole strand. Half strand 7′ is tucked until cover 2 is reached, whose yarns are divided and 7′ passed through them and drawn under the two adjacent strands, forming again the lock. The strand ends at both locks are now cut off, leaving about 2 ins., so that the yarns may draw slightly without unlocking. This completes the joining of one pair of strands (fig. 6,084). The remaining pairs are joined in the same manner. After the rope has been in service a few days, the projecting ends at locks wear away, and if tucks have been made carefully, and original twist of yarns preserved, the diameter of the rope will not be increased, nor can the splice be located when rope is in motion.

Wire Ropes.—If made flexible, that is, with a hemp core to each strand and a central hemp core to the rope itself as well, wire ropes will stand a strain in lbs. approximately equal to the square of the circumference in inches multiplied by 600.

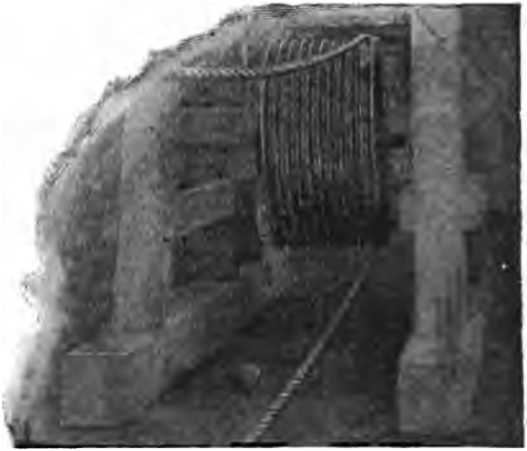


FIG. 6,085.—Method of springing transmission rope from first to second groove. Before putting new rope on sheaves, keep it in a warm, dry place for a day or two. Take out as much stretch as possible with tackle, when measuring on sheaves, but do not stretch the life from the rope by subjecting it to abnormal strain for days before putting it in service. Beware the old sailor who has been splicing ropes all his life, and, of course, "knows it all"; his ship splice is fatal to a transmission rope, nor is there any coupling device which is satisfactory. Where many ropes are to be installed on large sheaves for the *multiple system*, the first rope is spliced and sprung into the outer groove of each sheave. A wedge is then placed on both sheaves at the point where the rope enters this groove, and as the sheaves are slowly revolved, the rope is forced into the second grooves. The wedges are in turn removed to the second grooves, and while the next rope is being sprung in place in the first grooves, by the revolving of the sheaves the first rope is forced into the third grooves. This process is continued until the first rope has reached the middle groove, when the remaining ropes are put on in the same manner from the opposite side of the drive.

NOTE.—A *wire rope* may be spliced in practically the same manner. Some six to eight feet for small sizes, or proportionately longer for larger wires, is marked off, tied with marline, and unlaid as with rope, the core being cut out. As the strand in one rope is unlaid, the corresponding strand from the other is laid in its place; each meeting point should be temporarily tied, and the ends cut off to a similar length. Care must be taken that the succeeding pairs of strands stop well short of the preceding ones. When all the pairs of strands are tied and in place, the rope should be taken to a vise and untwisted by hand beyond the outside pair of strands. As the rope opens, an assistant with nippers must cut the core, and as he slowly pulls it out, the operator must follow with the wire end, tucking it into place. The rope is then allowed to close on itself, and untwisted further along, pulling the core out in the opposite direction and crowding the wire into its place. These operations are performed in succession at each meeting place of two strands; the rope being hammered lightly with wooden mallets at the spliced points to make all lie smooth. Some seamen simply tuck the ends through the centre and out the other side, cutting the protruding wires: this, however, is not such a finished method as the first described.

That is to say, a rope termed "three-quarters," that is, with a diameter of about ¾ inch and a circumference of 2¼ inches, will stand safely 3037.5 lbs., having then a factor of safety of seven.

Wire ropes need to be kept clean from rust, etc., and should be lubricated when running; graphite being as good as anything. Once a month the rope requires to be carefully oiled with raw linseed oil, well rubbed in.

So called flexible wire ropes should ***not be worked*** around a sheave or drum having a less diameter than ***six times the girth of*** the rope; harder and stronger ropes, such as are used for winding from great depths, should not pass over any wheel of a less diameter than ***ten times the girth.*** The smaller figures are for ropes worked at a slow speed only; for each increase in speed the pulley should also be enlarged. This must specially be insisted upon with ***elevators*** and ***lifts***, in which case itis advisable to exact ***ten*** as a minimum ratio.

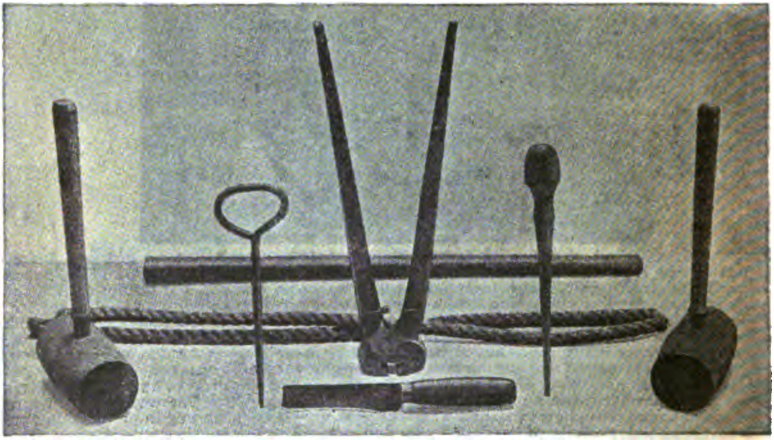


FIG. 6,086.—Tools required for splicing wire ropes.

How to Splice Wire Rope.—The accompanying series of cuts illustrating the splicing of wire rope are from photographs taken during the splicing of a one inch diameter regular lay rope, with six strands and a hemp center, and are intended to cover every part of the work.

The making of rope splices at mines, and other places of operation, is usually intrusted to men who possess some mechanical skill and facility in handling tools. It follows, as a matter of course, that the higher the degree of skill and care employed, the more satisfactory will be the result, and it would, therefore, be well for those who are entirely lacking in experience to make one or two practice splices before attempting to splice a rope which will be subjected to severe conditions in actual use.

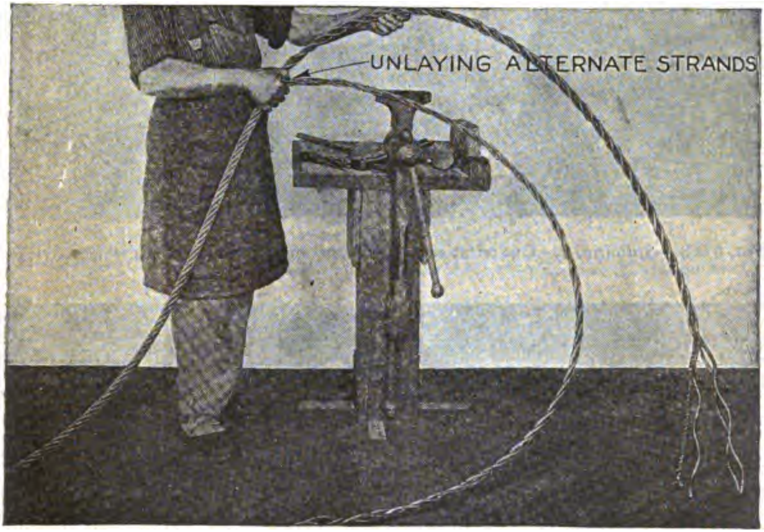


FIG. 6,087.—***Splicing Wire Ropes, 1.*** Measure back from the ends which are to be spliced for a distance of ten feet. At these points bind pieces of wire firmly around the rope to prevent the strands untwisting further back. The distance of ten feet is usual upon ropes of the diameter under consideration, that is, one inch. Upon smaller ropes the distance may be slightly decreased, and with those larger than one inch an additional allowance is advisable. After the wires have been bound around the rope, in the manner directed, unlay three alternate strands at each end back to these binding wires. It is important that the strands should be alternate, that is, if we assume them numbered in regular order from No. 1 to No. 6 and No. 1 is unlaid first, the next to be unlaid should be No. 3 and not No. 2. The illustration shows the rope after the three strands have been unlaid.

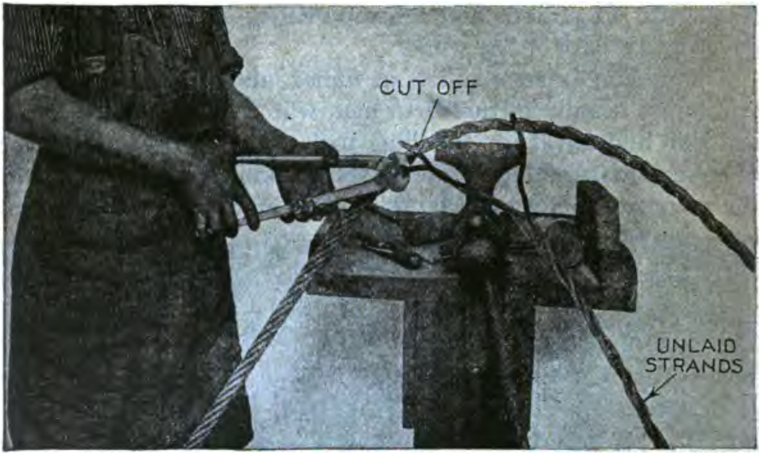


FIG. 6,088.—*Splicing, 2.* Cut off at each end of the rope the three strands which have just been unlaid.

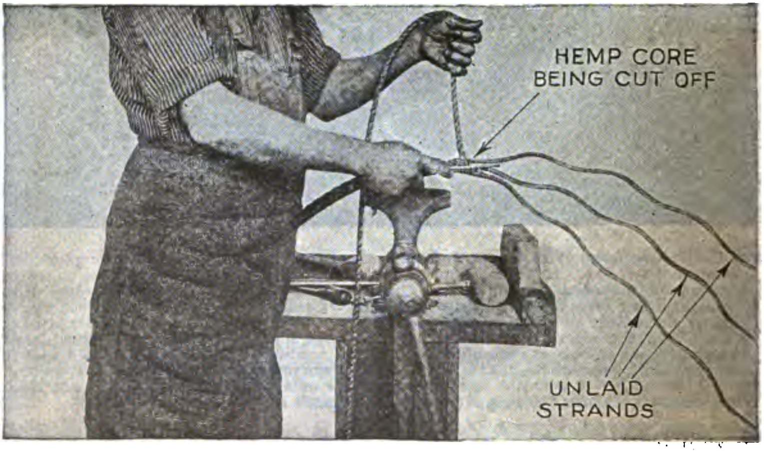

HEMP CORE BEING CUT OFF
UNLAID STRANDS

FIG. 6,089.—*Splicing, 3.* Separate the remaining three strands at each end back to the point where the other strands were cut off. This will make each of the two ends of the rope have three strands separated from each other for a distance of ten feet. The hemp cores should be cut off at each end as shown.

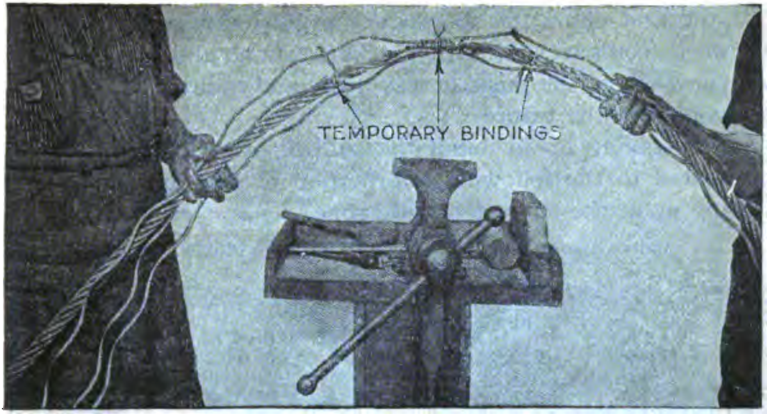


Fig. 6,090.—***Splicing, 4.*** Bring the two ends of the rope thus prepared face to face, so that the corresponding strands for each end interlock regularly with each other in a manner similar to that in which the fingers will interlock when those of one hand are pushed between those of the other. Each of these strands must be laid into the rope for its full length as illustrated in the cut following. Temporary bindings of wire should be made around the strands where they interlock to hold them in position for the subsequent operations.

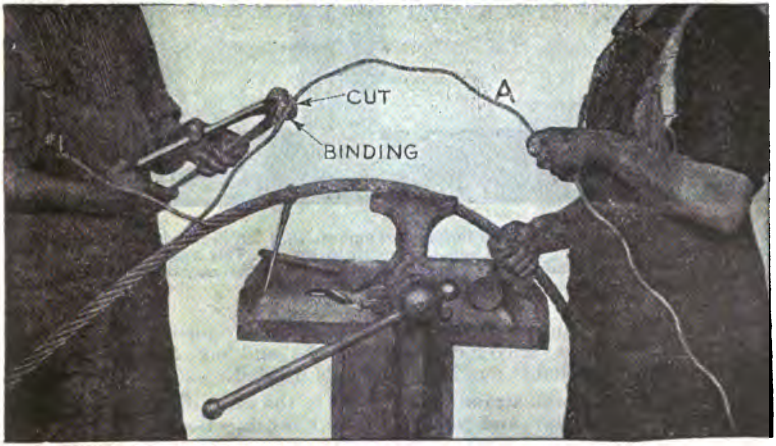


Fig. 6,091.—***Splicing, 5.*** Unlay any one strand A, and follow up with strand No. 1 from the other end, keeping it tightly in the open groove left by the unwinding of A, making the twist of the strand agree with the lay of the open groove.

If the first effort fail to produce a good result, a review of the work, comparing it with the illustrations and instructions, will show where the mistake was made and indicate what must be avoided in the future.

Before taking up in detail the subject of splicing, attention is directed to the following information of a general character bearing upon the subject of wire rope.

The standard wire rope consists of six strands twisted around a hemp center. This arrangement affords the most convenient and compact form, but it may be varied for special purposes, and four, five, seven, eight nine, or any reasonable number of strands utilized.

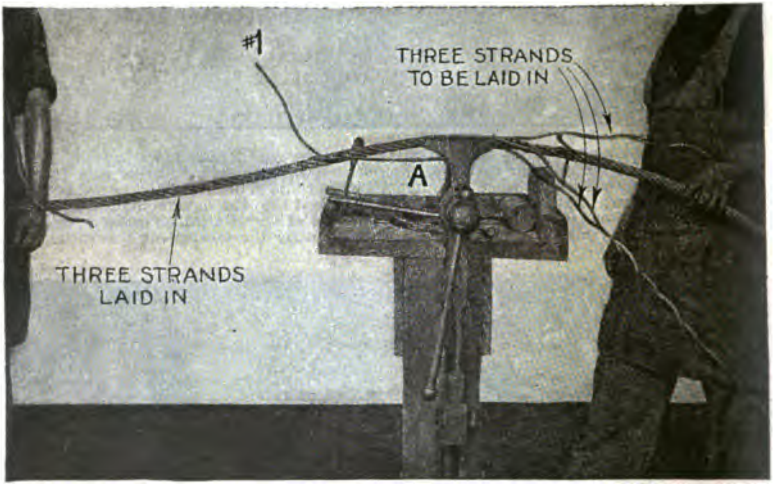


Fig. 6,092.—*Splicing, 6.* When all but a short end of No. 1 has been laid in, the strand A should be cut off, leaving an end equal in length to No. 1. This length should be, for a one inch diameter rope, about ten inches. For a smaller rope this may be slightly decreased and for a larger diameter an increased length is desirable.

When the wires and strands are twisted in the same direction, the rope is known as a lang lay, and when in the opposite direction it is known as a regular lay rope. A wire strand is sometimes used instead of a hemp center. This adds somewhat to the strength of the rope, but it causes it to wear more rapidly and its use is not generally advised.

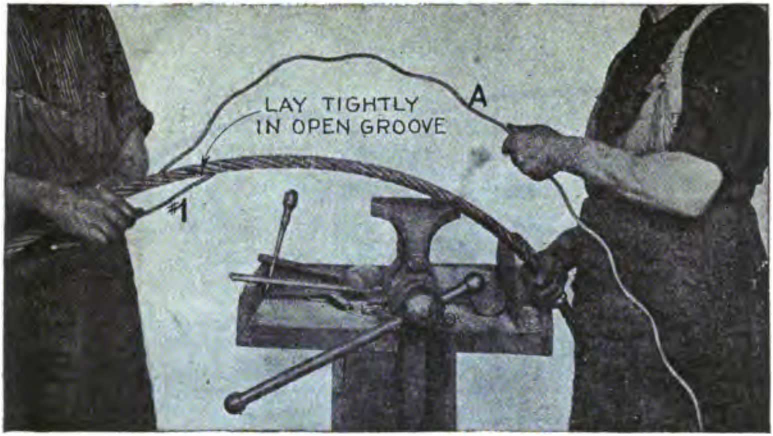

LAY TIGHTLY IN OPEN GROOVE
A
#1

Fig. 6,093.—***Splicing, 7.*** Unlay another strand in the same manner that A, was unlaid, and follow up as was done with strand No. 1, stopping, however, back of the ends of A, and No. 1. The unlaid strands should be cut off as A was cut, leaving two short ends equal in length to those of A, and No. 1. The distance between the points where the ends project should be about two feet. The illustration shows the rope after the three strands on one side of the joint have been laid in the manner described. There now remain the three strands on the other side, which must be laid in the same way.

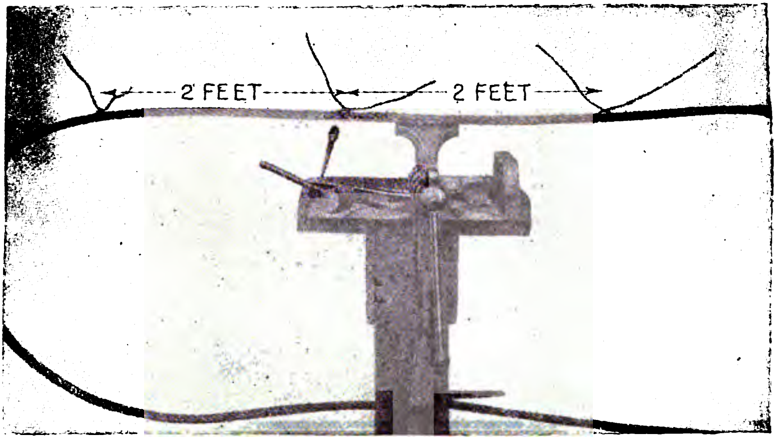


Fig. 6,094.—***Splicing, 8.*** Clearer view of the projecting ends after the first three strands have been laid in as described in fig. 6,093.

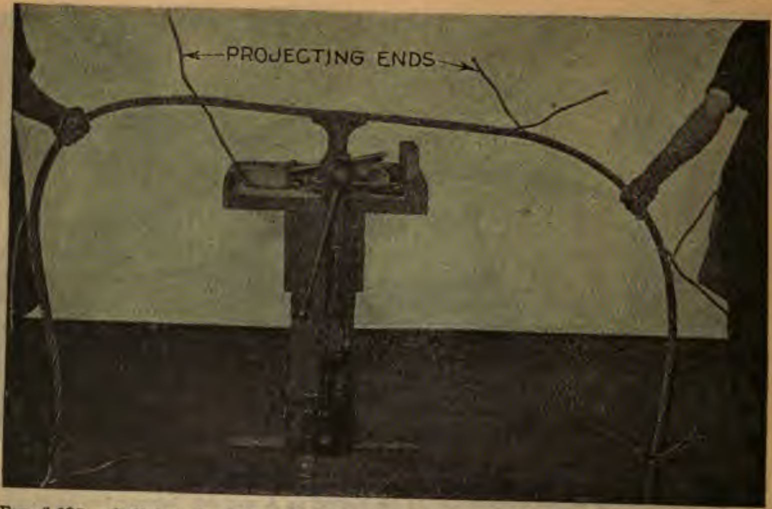


FIG. 6,095.—***Splicing, 9.*** When all six strands have been laid in, as directed, the splice will appear as here shown. There will now be six places at which the ends of the strands extend ten inches beyond the rope These ends must be secured without increasing the rope's diameter, as directed in the cuts following.

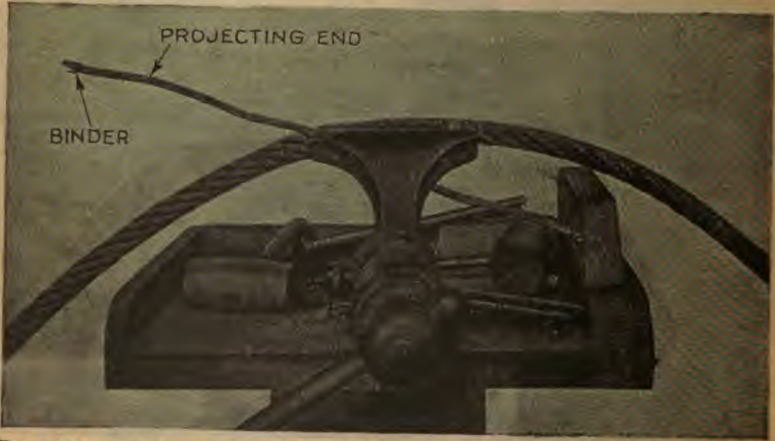


FIG. 6,096.—***Splicing, 10.*** Place the rope in a vise at one of the points where the ends extend as above.

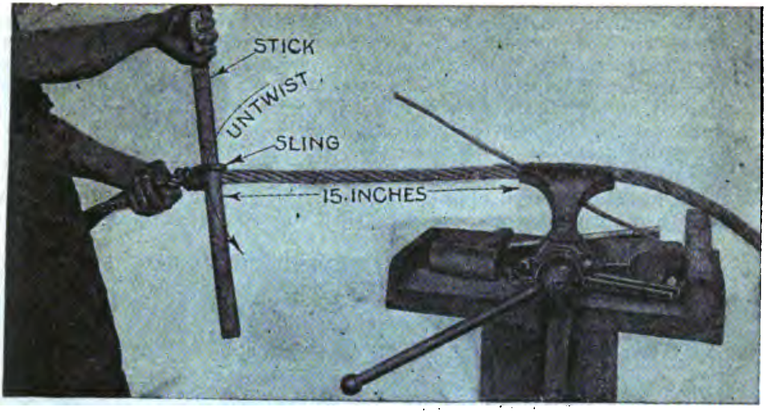


Fig. 6,097.—***Splicing, 11.*** Bind a short piece of hemp rope around the wire rope, about fifteen inches back of the vise, so as to make a sling, and insert stick in loop. Pull the end of the stick so that the wire rope will be untwisted between the vise and the stick.

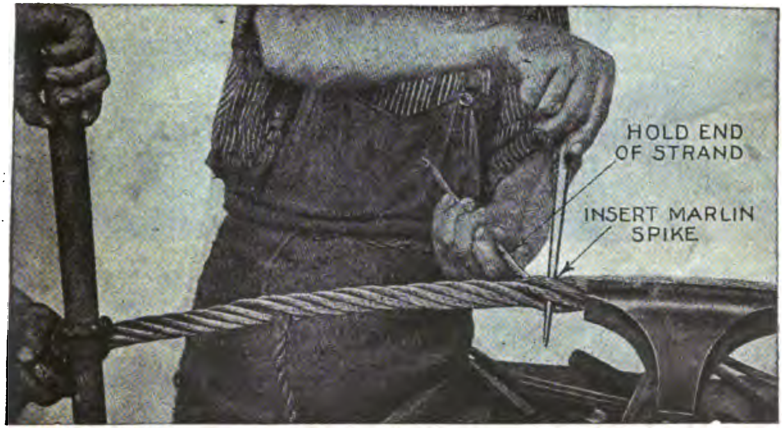


Fig. 6,098.—***Splicing, 12.*** The rope, by means of the stick, may be untwisted sufficiently to insert the point of the marlin spike under two strands. Use the pick to force the hemp core into such a position that it may be reached by the knife and cut. It will be noticed that the end of the strand which is to be laid in, has been bent back toward the vise. As this end must follow the twist of the rope and occupy the space left vacant by the removal of the hemp core, the end itself should have some tendency to twist in the proper direction. Bending the end back and giving it one twist in the direction of the twist of the rope will impart this tendency

The strands usually consist of seven, twelve or nineteen wires each. These wires are drawn from iron, cast steel, plough steel, blue center steel and occasionally from copper and bronze. The various kinds of rope are manufactured for use under conditions to which they are best adapted, and while their use is not always restricted to these conditions, better satisfaction is given where they are considered. For this reason, if any doubt exist as to the size or style of rope required, it is well to write to the manufacturer for advice before ordering.

If a rope be received upon a reel, the latter should be mounted upon a spindle or turn table and the rope then run off. If slipped in a coil it should be rolled along the ground like a wheel or hoop and not uncoiled like a hemp rope. Be careful to have the drums and sheaves for wire ropes of sufficiently large diameter.

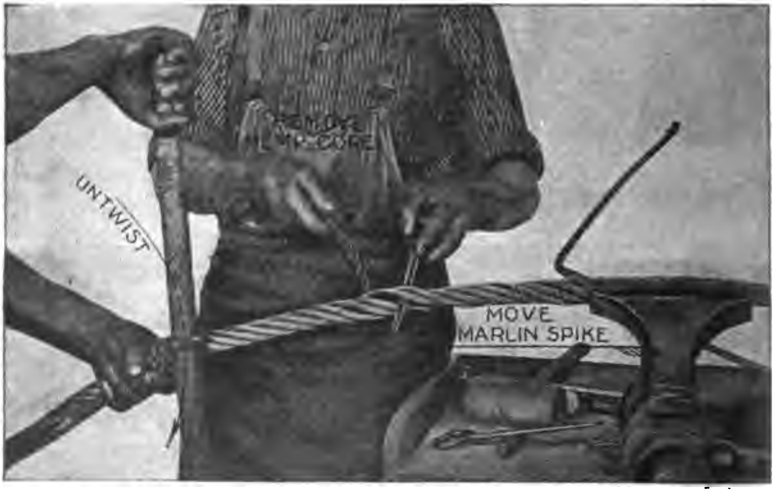


FIG. 6,099.—*Splicing, 13.* After the hemp core has been cut, it should be removed for a distance equal to the length of the projecting end of the strand. This may be done by moving the marlin spike along the rope with one hand while the other removes the hemp core. The marlin spike should be under two strands of the rope as shown.

Many ropes fail to give satisfaction through running at high rates of speed over small drums and sheaves. It is also important to keep the surfaces of the drums and sheaves smooth and free from any projections which would tend to cut or wear the wires. When ropes are used for ship's rigging, derrick guys, or under similar conditions, involving continued exposure to the elements, the wires are frequently galvanized.

Ropes subjected to constant bending around drums and sheaves are

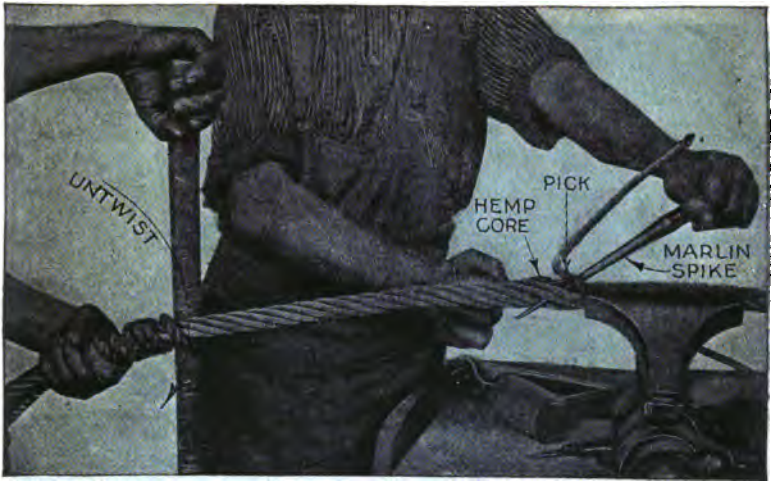


FIG. 6,100.—***Splicing, 14.*** Insert the marlin spike so that it will be *over* the projecting end and under the next two strands of the rope. Pull the marlin spike toward yourself. This will cause it to travel along the rope, leaving an opening in front. While one hand is employed in moving the spike, the other hand holding the end of the strand should lay this end into the opening, as indicated.

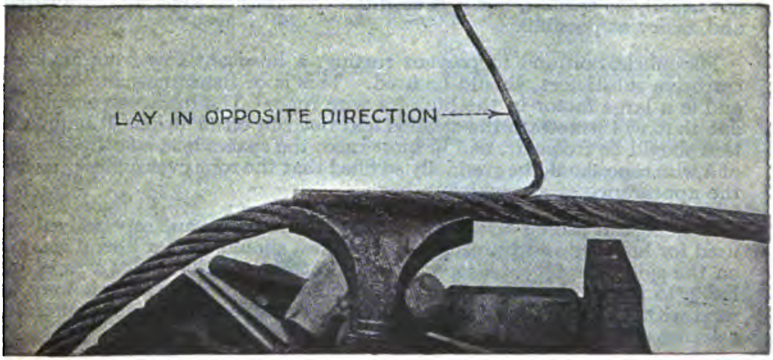


FIG. 6,101.—***Splicing, 15.*** This illustration shows the rope after the end of one strand has been laid in. The end still projecting must be laid in the same manner but in the opposite direction. This should be repeated at each of the places where the ends project until all are laid in.

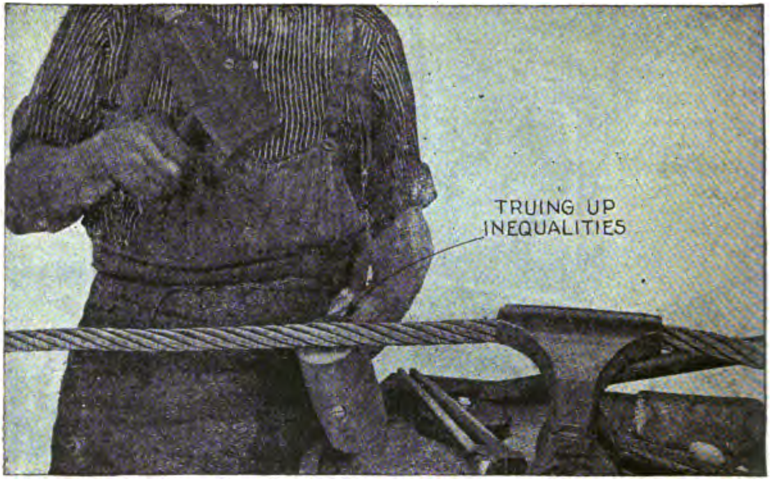


FIG. 6,102.—*Splicing, 16.* After an end has been laid, cut off the projecting end of hemp core and hammer down any inequalities with the wooden mallets. With practice a splice can be made which will be impossible to detect after the rope has been running a day or two.

not usually so treated, but it is essential that they be kept well lubricated and as dry as possible.

For lubrication and to prevent rusting, a lubricant free from acids or corrosive substances, should be used. This is of the utmost importance, and is a large factor in the life of a wire rope. The lubricant should be one that will penetrate the strands and not run off or drip. Its application should be frequent, and in most cases the spaces between the strands of a wire rope should be gradually so filled that the rope eventually presents the appearance of a round iron bar.

In general it should be remembered that wire ropes, and especially those used for hoisting and transmission purposes, should have a liberal margin on the side for safety. Proper care and attention will render a rope less liable to injury through external conditions, but in order that it may be used without danger to life and property, it must be well made of carefully selected materials.

It is sometimes a costly error to assume that a rope is cheap because it sells for a low price. Its value is measured by its service, and the amount saved in the purchase of an inferior rope may be lost many times over in an attempt to repair the damage caused by its failure.

READY REFERENCE INDEX

A

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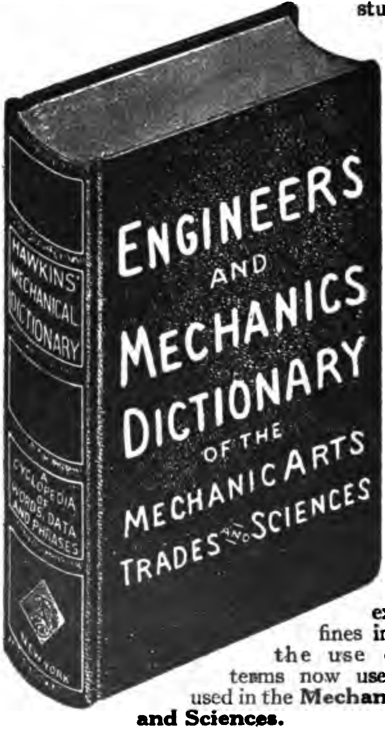

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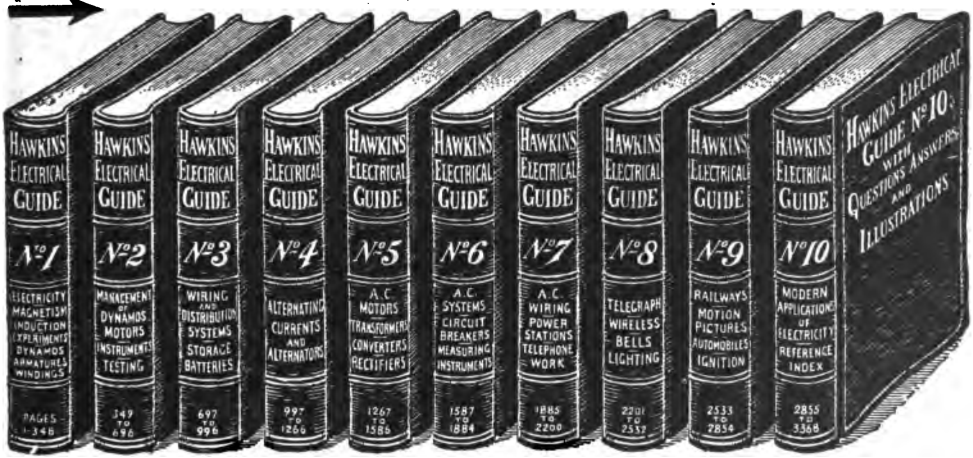
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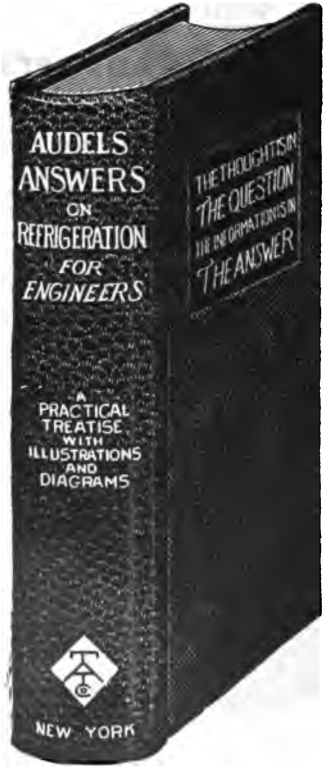

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